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The mysterious rumbling waking up Mars

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Health
Why you've been thinking about fat all wrong

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Can the UK meet its ambitious targets?

Time
Could you live without clocks or natural light?

Time to build together

Joel & Mia

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FROM THE EDITOR

Between 1994 and 1995 a man lived in space, aboard the Mir Space Station, for 438 consecutive days – the most anyone has spent in low-Earth orbit. To me, that's an unimaginable amount of time to spend locked in a capsule spinning around the Earth at just under 28,000km/h. But for Valery Polyakov, it didn't seem like a big deal, at least that's what the history books say. Polyakov, a physician who had been studying the effects of spaceflight on the human body, had volunteered for the mission to find out what the consequences of longer term spaceflight might be. He was keen to find out how realistic a goal a mission to Mars might be.

It turns out Valery was made of some pretty tough stuff, experiencing few unexpected side effects and noting only that his mood was affected for the first few days aboard the space station. As if to show that the body could overcome the perils of long periods in space, Polyakov would exercise for two hours a day. When he landed, keen to prove a point, he lifted himself out of the Soyuz landing craft and walked over to the medics waiting for him – most astronauts' muscles waste away after living gravity-free for a few hundred days – which earned himself the nickname 'the ironman of spaceflight'. Today, it seems like that the extended missions Polyakov envisioned will soon become a reality. Space agencies are plotting landing sites on the Moon, and from there it's a short hop (okay, maybe not that short) to Mars. In this issue we look at how our biology, and that of the plants and animals we'll have to bring with us, will survive on other worlds.

Daniel Bennett, Editor

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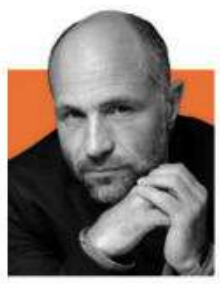

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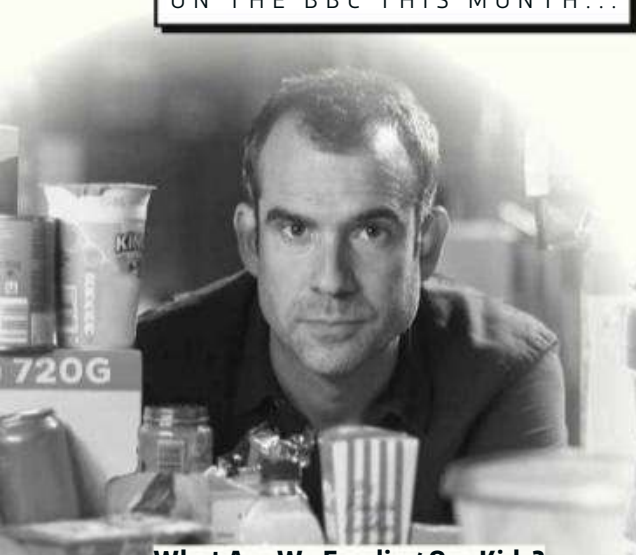

What Are We Feeding Our Kids?
Is ultra-processed food causing obesity in children, and could it even be addictive? Dr Chris van Tulleken investigates as he undergoes a gruelling self-experiment that shocks the scientists.
BBC One,
Friday 11 June, time TBC

CrowdScience
How old are the elements? Is my noisy neighbour affecting my health? Why do I have a sweet tooth? These are just some of the brilliant questions the *CrowdScience* team will be diving into this month.
BBC World Service,
bbcworldservice.com/crowdscience

Prepper
Sylvia (Sue Johnston) and Rachel (Pearl Mackie) are back with a new series of their hit comedy podcast featuring two very different women gearing up for the end of the world. Wasp flu, zombies on street corners... They're prepared, are you?
BBC Radio 4
Friday 11 June, 11:30am

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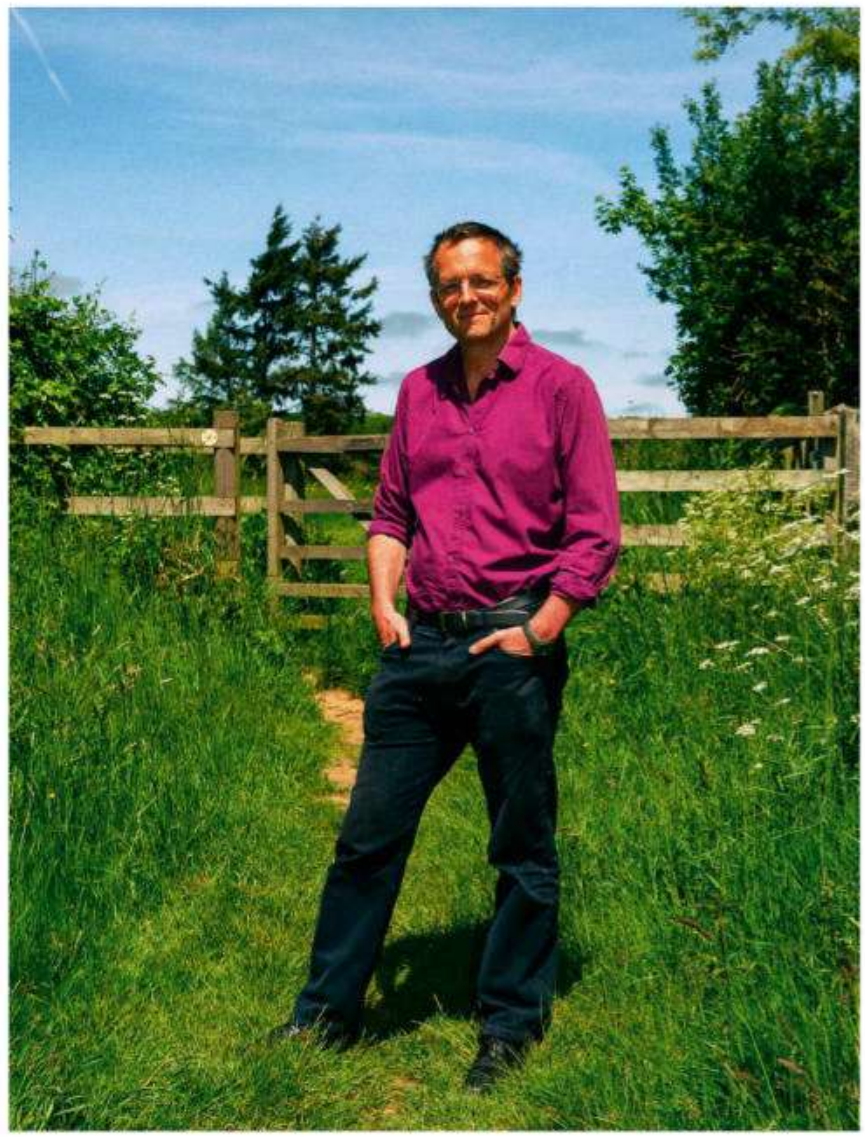

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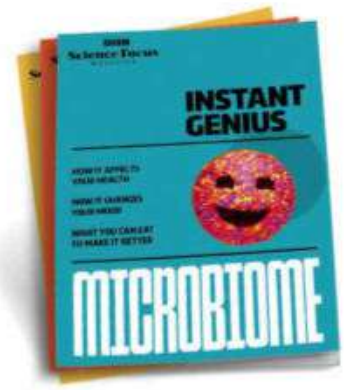

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EYE OPENER

Follow the light

REYKJANES PENINSULA,
ICELAND

The light show captured in this long-exposure photo is part natural and part artificial. The yellow, red and orange on the left of the image is a volcanic eruption near Iceland's Mount Fagradalsfjall, around 40km (25 miles) from Reykjavík. The white trails leading to and from the eruption are torches carried by locals hiking up to watch it.

Lava began spewing from a fissure near Mount Fagradalsfjall on 19 March and continued to emerge through April and into May. The eruption hasn't been explosive, however, so authorities deemed the danger to be low and permitted visits to the site.

"Fagradalsfjall hasn't seen any sort of activity since the 12th Century," says volcanologist Dr Jazmin Scarlett. "But what's interesting is that recent readings show the eruption is gaining strength. Almost all eruptions are most powerful at the beginning and lose energy, but this doesn't seem to be happening here."

THEO BOSBOOM/NATUREPL.COM

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EYE OPENER

Hanging out

TOKYO, JAPAN

Kengoro is one cool robot, in every sense of the word. Built by roboticists at the Jouhou System Kougaku (JSK) Lab, at the University of Tokyo, it's been made to mimic human movements as closely as possible. To that end, Kengoro has an analogous musculoskeletal system that enables it to do pull-ups, sit-ups, stand on its toes and more. But all this exercising provokes Kengoro's most human-like characteristic of all: sweating.

Kengoro's skeleton is permeable, thanks to microchannels in its 3D-printed 'bones'. When it's working out, water is pumped through the bones and permeates to the surface where it evaporates to cool the bot down. Sweating enables Kengoro to do press-ups for 11 minutes – more than most humans, let alone robots, can manage.

"Bio-inspired technologies like those on Kengoro will enable better joint replacements that will help keep our bodies functioning longer," says Dr Peter J Bentley, a computer scientist at UCL.

ALESSANDRO GANDOLFI/ PARALLELOZERO

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EYE OPENER

Glass jaw

TENERIFE,
CANARY ISLANDS

The creature sizing you up here is a fangtooth moray (*Enchelycore anatina*) and almost everything about it seems intended to give you nightmares. Aside from the eel's threatening stare, its yellow and black colouration, and its size (up to 120cm), there's that gaping mouth bristling with rows of razor-sharp, glass-shard teeth.

But provided you're not a crustacean swimming among the rocks and reefs below the surface of the northeast Atlantic, you've got very little to fear. If you are, however, and you happen to get too close to where a fangtooth moray is lying in wait, things get truly terrifying. Because while the teeth you can see are scary, it's the ones you can't see that you need to worry about.

The fangtooth, like other morays, has another set of teeth on a second pharyngeal jaw buried in the back of its mouth. Once the prey is caught in the eel's first set of teeth, the second set thrusts forward and pulls it down the eel's throat where it's swallowed alive. Sleep well.

SERGIO HANQUET/NATUREPL.COM

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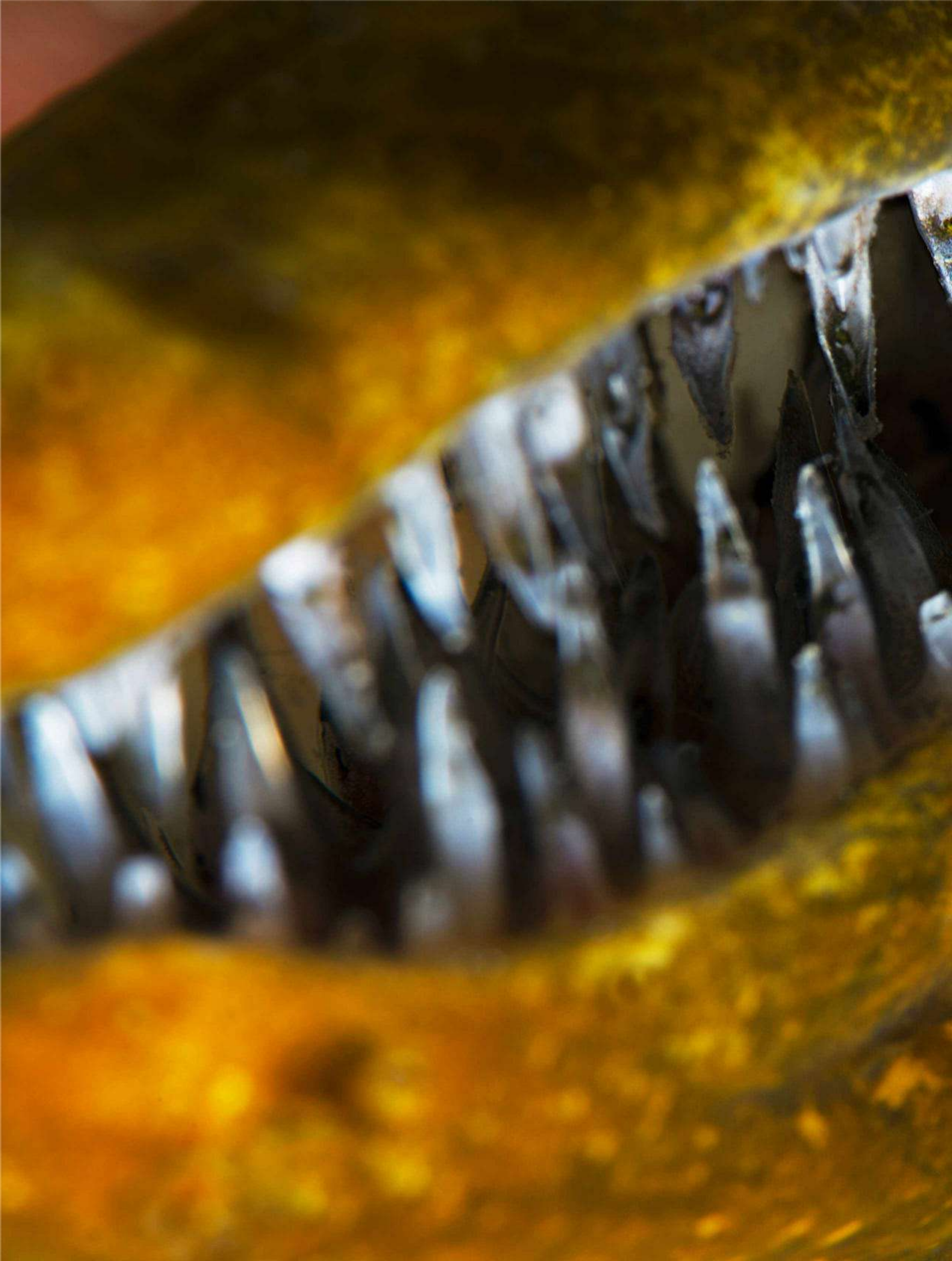

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

A different kind of exploration

I spent the best part of my 20s and 30s exploring the world. I've stayed on every continent, and have seen and experienced amazing things – I know I'm lucky! All that time I've read every single issue of this magazine, and I adore it. Now, in my late 40s, I'm as settled as a man like me can be. I am now a nurse and the last year has been extremely hard work, emotionally and physically.

Your April issue about exploration touched me profoundly. We have used our desire to explore to advance our species. I believe that this is why lockdown has been so hard on people: whether they realise it or not, we are all explorers.

I'm immensely proud of this country and how the majority of us have quashed our desires to keep us all safe. I'm extremely proud of my colleagues and how we've 'explored' new ways of working to the best effect to get us through these tough times. Let's keep safe and get through the rest of this situation.

Tomo Hawk, Portsmouth

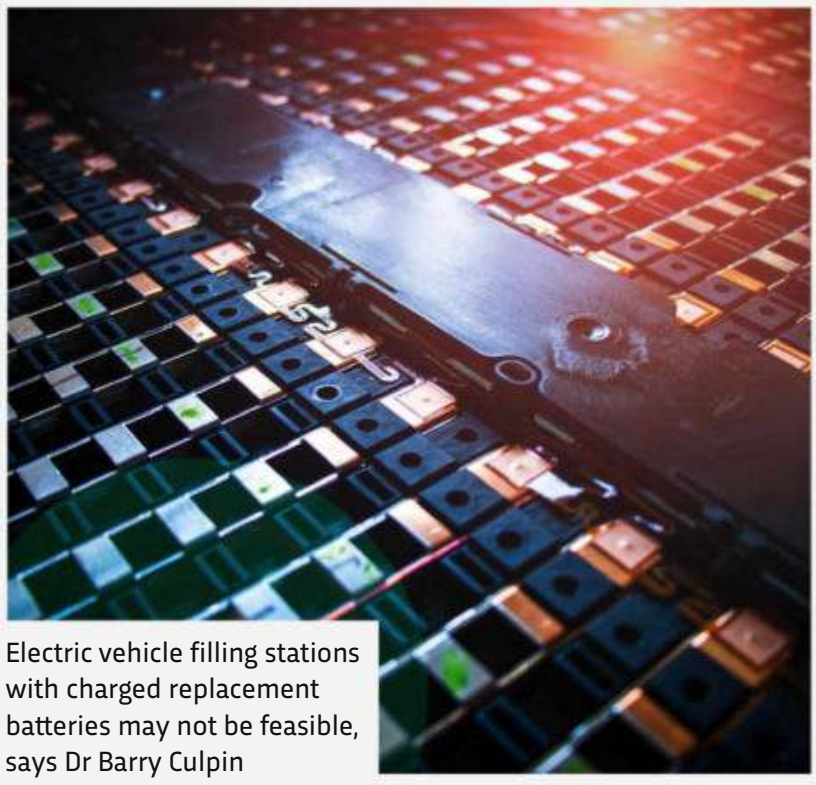
WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins **Nanoleaf Shapes**. Nanoleaf Shapes have 16 million customisable colour combinations to choose from and panels that react to music and your on-screen activity, so you can create your own patterns and designs to quickly transform any space. Each panel can be controlled by a simple touch, through your smart home system, or via the Nanoleaf app. **nanoleaf.me**

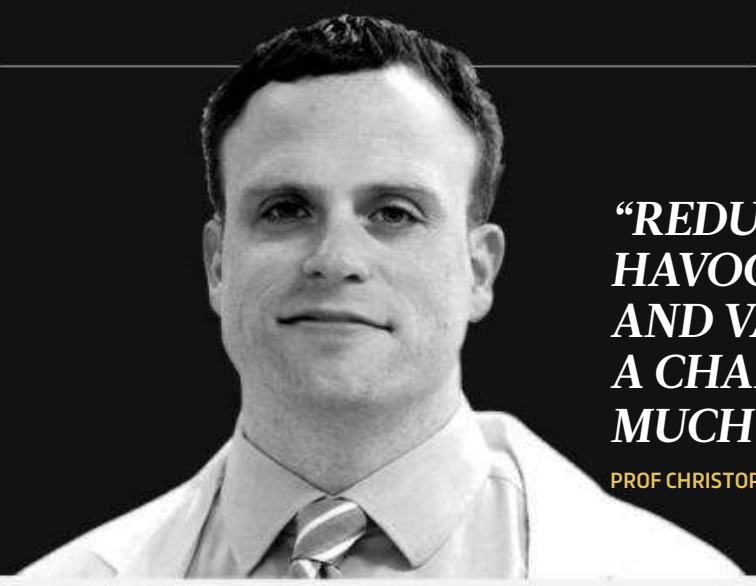
Squash the stink

I have only now read one of your Q&As from February 2020 which mentioned apples to combat the smell of garlic on the breath. While this may work, try parsley – it works a treat. As I live in France I should know!

Tim Hope

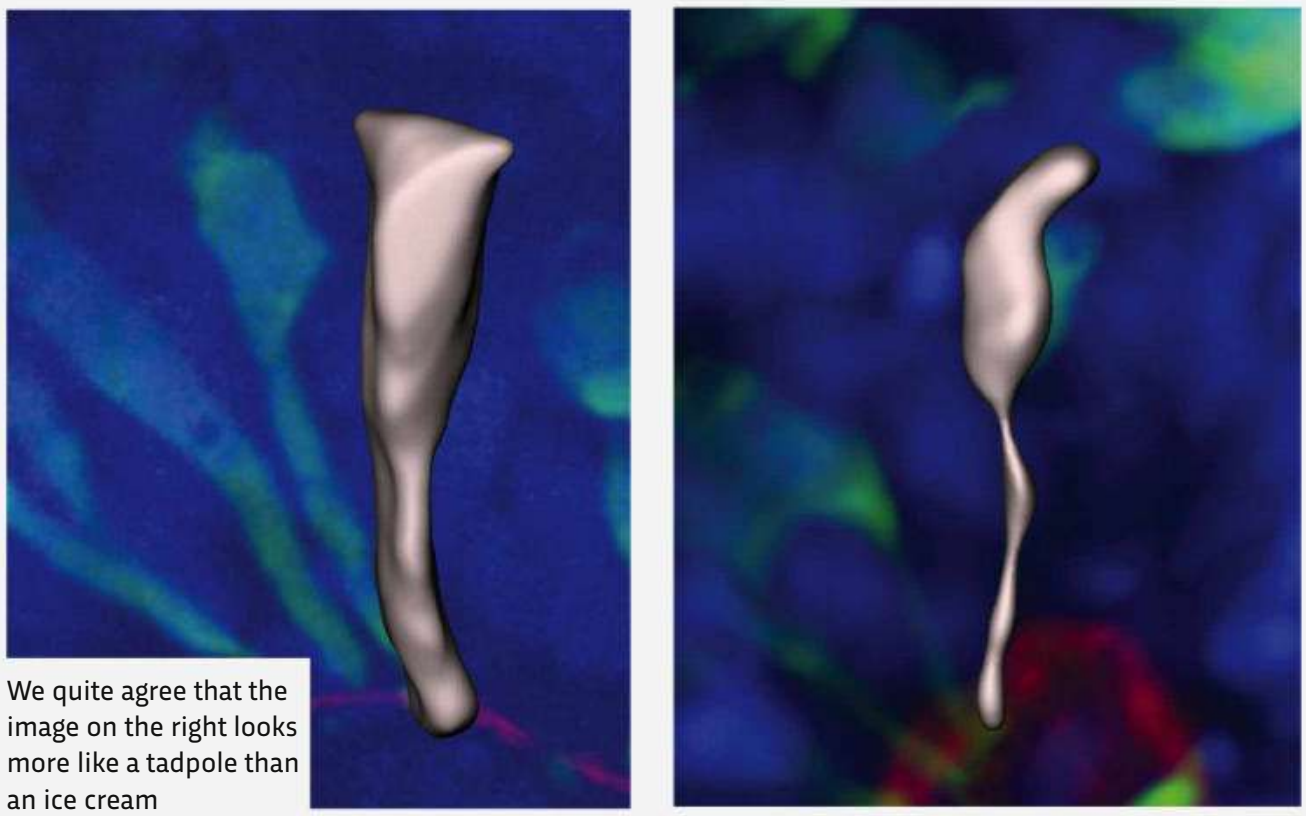


Electric vehicle filling stations with charged replacement batteries may not be feasible, says Dr Barry Culpin



"REDUCED GRAVITY WREAKS HAVOC WITH THE IMMUNE AND VASCULAR SYSTEMS. THAT'S A CHALLENGE AND THERE'S NOT MUCH WE CAN DO ABOUT IT"

PROF CHRISTOPHER MASON, P66



We quite agree that the image on the right looks more like a tadpole than an ice cream

GETTY IMAGES X3, S BENITO-KWIECINSKI/MRC LMB/CELL

Falling flat

Following on from Richard Lindley's suggestion on your *Conversation* page that electric vehicle batteries could be swapped at a 'filling station' (April, p13), this was suggested some years ago but has never been taken up. I suspect the reasons for this include: 1. The performance of batteries degrades with use, and conventionally a battery is replaced when it has declined to 80 per cent capacity. If the battery has been fast-charged many times its performance might be less than that. Would a driver be happy to swap their new, fully performing battery for an old one with a suspect performance? 2. To make the system manageable, the car manufacturers would have to agree on a small range of batteries for all electric vehicles. This would limit a vehicle manufacturer's design scope as their cars would have to fit the battery. 3. The filling station would have to keep a considerable stock of charged batteries of all types to cater for any demand. If a motorist arrived with a flat battery and a charged replacement was not available they would have a long wait for one to be charged, negating the advantage of a battery swap.

Dr Barry Culpin

Two scoops of tadpoles, please!

Are you sure that the two pictures on p20 in the April edition are printed the right way? The image caption says that the human cells (left) remain cylindrical, and the gorilla's grew into a cone shape. It looks more like the human cells are an ice-cream cone shape, and the gorilla's are a tadpole shape. Just like the thousands that we have in our pond right now – tadpoles, that is!

Colin and Christine Lang

Yup, they are the right way round (we double-checked). Maybe the scientists involved have only ever had some very depressing, squashed ice creams in their time. They need to get a Mr Whippy, pronto!

Alice Lipscombe-Southwell, *managing editor*

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SOMETHING'S RUMBLING ON THE RED PLANET

Mounting evidence suggests Mars isn't dead

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Soothing cyborgs Robots with sympathetic gestures show promise as counsellors p21 **Box of tricks** Cats love sitting in boxes, even ones that aren't there p22 **Scratch that itch** New wearable sensors measure eczema sufferers' scratching p23

Volcanoes on Mars could've erupted as recently as 50,000 years ago, a study carried out by researchers at the University of Arizona using data from satellites orbiting the planet has found.

Previous studies have suggested that most of Mars's volcanic activity occurred between three and four billion years ago, with some outlying eruptions continuing in isolated locations until about three million years ago.

"This may be the youngest volcanic deposit yet documented on Mars," said lead author Dr David Horvath, who worked on the study as a postdoctoral researcher at the University of Arizona and is now a research scientist at the Planetary Science Institute. "If we were to compress Mars's geologic history into a single day, this would have occurred in the very last second."

The volcanic deposit was found in Elysium Planitia, a smooth, flat plain located just north of the equator. The eruption produced an 11km-wide, smooth, dark deposit surrounding a 32km-long volcanic fissure, and could have spewed ash and rock up to 10km into the Martian atmosphere. The composition and distribution of the material deposited is similar to what would be expected for a pyroclastic eruption – an explosive eruption of magma driven by expanding gases, similar to what happens when you open a bottle of sparkling wine.

"The interaction of ascending magma and the icy substrate of this region could have provided favourable conditions for microbial life"

Some hallmarks of the volcanic deposit also raise the possibility of there being conditions capable of supporting microbial life below the surface of Mars.

"The interaction of ascending magma and the icy substrate of this region could have provided favourable conditions for microbial life fairly recently and raises the possibility of extant life in this region," Horvath said.

The site of the eruption is around 1,600km from NASA's InSight lander, which has been studying seismic activity on Mars since 2018.

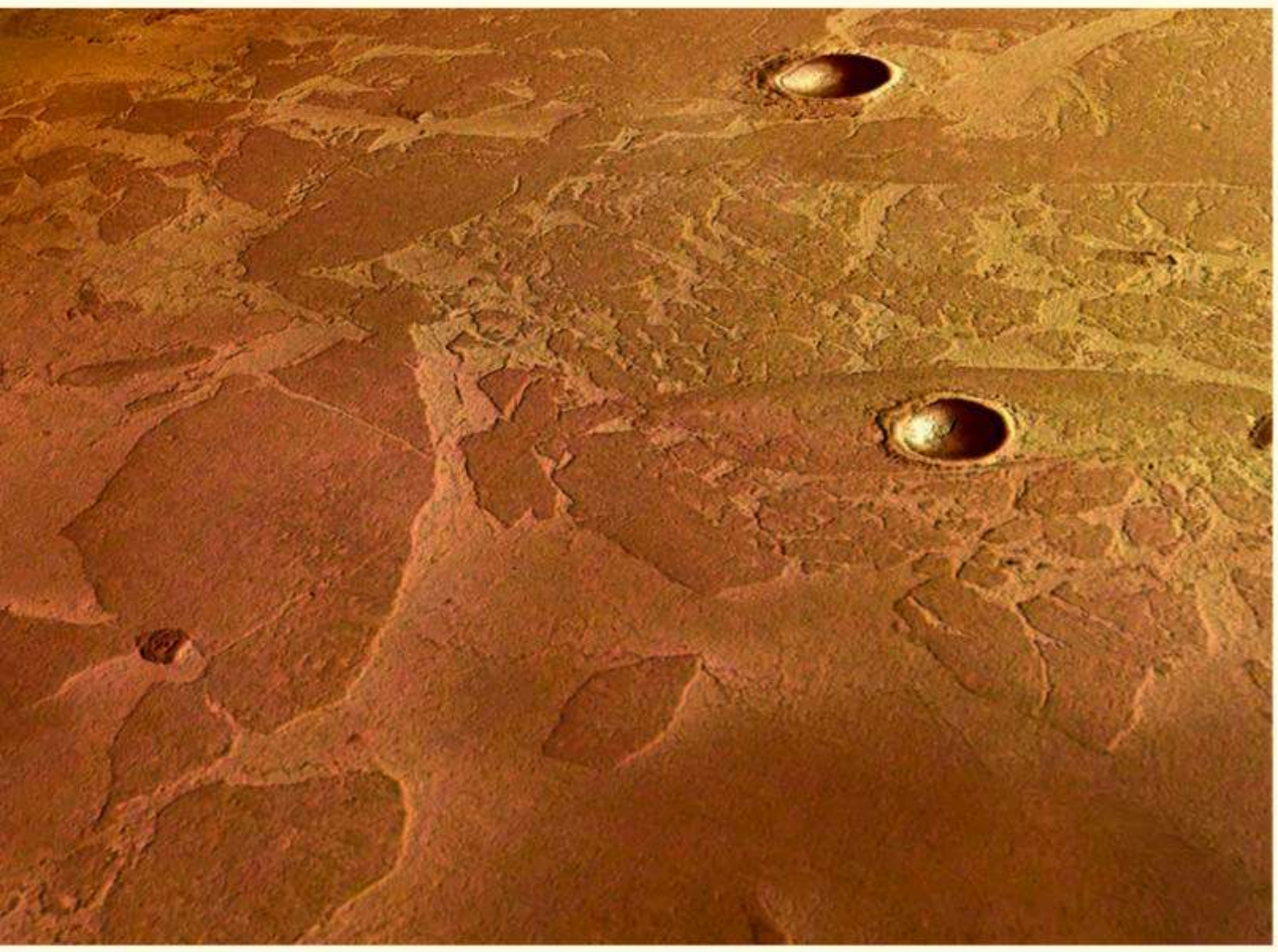
Further study is required to determine the exact nature of the eruption, but two marsquakes (the Martian equivalent of earthquakes) were found to originate around the Cerberus Fossae system of fissures in Elysium Planitia. Recent work has suggested the fissures could be due to movement of magma deep underground.

"The young age of this deposit absolutely raises the possibility that there could still be volcanic activity on Mars and it's intriguing that recent marsquakes detected by the InSight mission are sourced from the Cerberus Fossae," Horvath said.

The eruption may also have been due to a build-up of gases already present in the magma, or could have happened when the magma came into contact with permafrost, according to the researchers. It's also possible that the eruption was triggered by the asteroid impact that formed the nearby Zunil crater at about the same time.

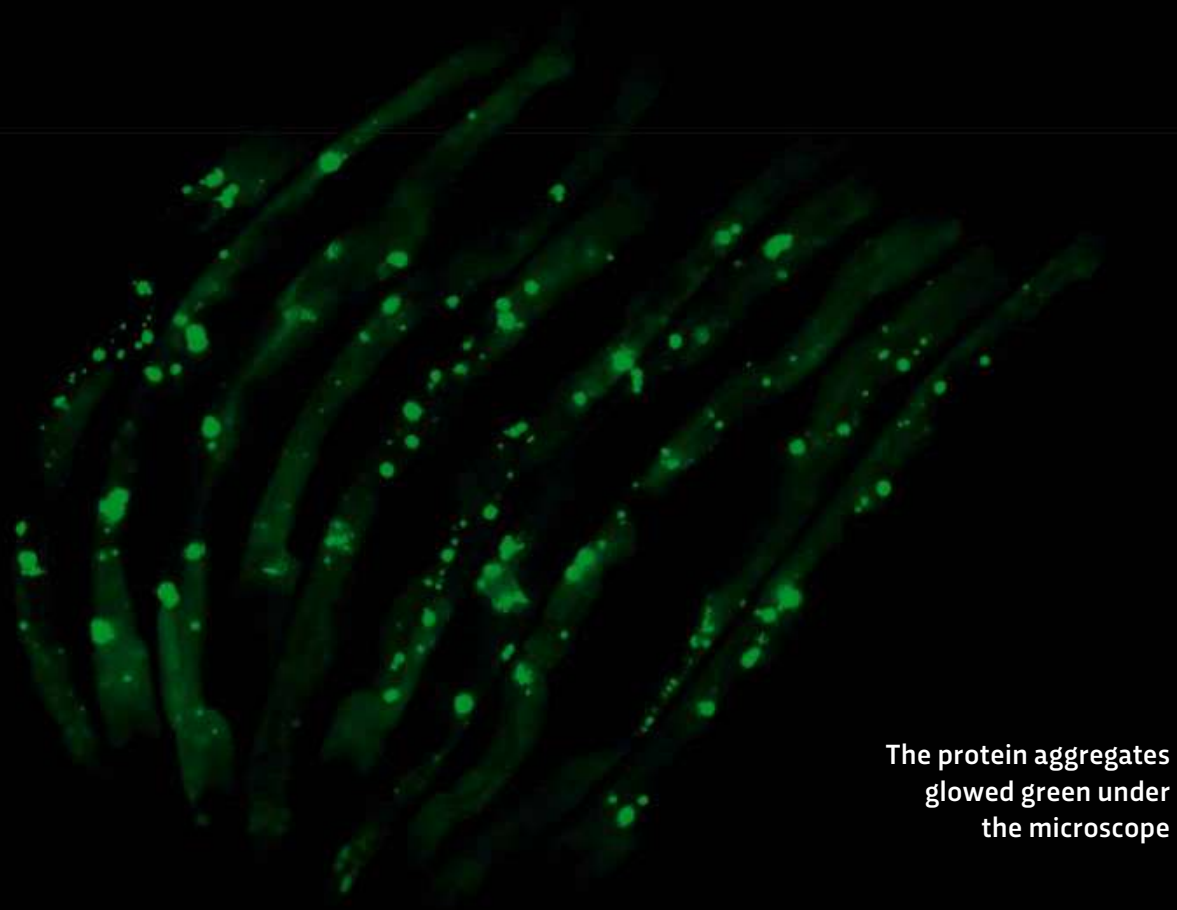
The volcanic deposit, along with ongoing seismic rumbling in the planet's interior detected by InSight, and possible evidence for releases of methane into the atmosphere detected by NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter, suggest that Mars is far from a cold, inactive world.

"This may be the most recent volcanic eruption on Mars, but I think we can rest assured that it won't be the last," said study co-author Jeff Andrews-Hanna, an associate professor at the University of Arizona Lunar and Planetary Laboratory. "All these data seem to be telling the same story – Mars isn't dead."



Elysium Planitia on Mars could have experienced volcanic activity in the last 50,000 years

ESA/DLR/FU BERLIN/G NEUKUM, UNIVERSITY OF FLORIDA



The protein aggregates glowed green under the microscope

MICROBIOLOGY

Scientists identify gut bacteria linked to neurodegenerative conditions

A study on worms points to gut bacteria that can kick-start Alzheimer's and Parkinson's, and ones that can counteract these conditions

Researchers have identified gut bacteria species that appear to play a role in the development of neurodegenerative diseases such as Alzheimer's, Parkinson's and motor neurone disease.

Previous research has found a relationship between these conditions and changes in the gut microbiome – the colonies of microbes that call our digestive system a home. Unfortunately, an individual's microbiome is made up of tens of thousands of species, so it has been tricky to untangle which microbes are involved in this effect. Now, researchers at the University of Florida have not only identified the harmful bacteria species, but have also shown that certain other species can produce compounds that counteract their impact.

"Looking at the microbiome is a relatively new approach to investigating what causes neurodegenerative diseases. In this study, we were able to show that specific species of bacteria play a role in the development of these conditions," said Dr Daniel Czyz, assistant professor at the University of Florida.

"We also showed that some other bacteria produce compounds that counteract these 'bad' bacteria. Recent studies have shown that patients with Parkinson's and Alzheimer's disease are deficient in these 'good' bacteria, so our findings may help explain that connection and open up an area of future study," he said.

Neurodegenerative disorders result from proteins building up in tissue in the body. These accumulations of proteins can interfere with cell function. The team studied the link between gut bacteria and neurodegenerative disease in a worm called *Caenorhabditis elegans*. When the worms were infected with the harmful bacteria, proteins began to aggregate in their tissues.

"We have a way of marking the [protein] aggregates so they glow green under the microscope," said Czyz. "We saw that worms colonised by certain bacteria species were lit up with aggregates that were toxic to tissues, while those colonised by the control bacteria were not."

The worms also lost mobility. "A healthy worm moves around by rolling and thrashing. When you pick up a healthy worm, it will roll off the pick – a simple device that we use to handle these tiny animals," said lead author Alyssa Walker. "But worms with the bad bacteria couldn't do that because of the appearance of toxic protein aggregates."

The team hopes to carry out further experiments in higher organisms and then, eventually, in humans.

In numbers

5

The number of migrations completed by PJ the cuckoo, a bird being tracked by the British Trust for Ornithology. It's the most ever recorded for the species.

2

million

The number of tiny CO_2 bubbles in a glass containing 250ml of lager, as determined by scientists at the University of Reims Champagne-Ardenne, France.

20

seconds

How long particles of urine and faeces can linger in the air after flushing a public toilet, according to a study at Florida Atlantic University. Best to flush then rush, then.

MEDICINE

New study bolsters support for 'magic mushroom' treatment for depression

Psilocybin, a psychedelic drug derived from magic mushrooms, may be more effective than one of the most commonly prescribed antidepressants.

Previous research carried out by a team based at NYU Grossman School of Medicine has shown that psilocybin has promise in alleviating treatment-resistant depression and anxiety in cancer patients. Now, a team based at the Centre for Psychedelic Research at Imperial College London has shown that the treatment could be at least as effective as escitalopram, a type of antidepressant known as a selective serotonin uptake inhibitor (SSRI).

The researchers studied 59 people with moderate-to-severe depression over six weeks. Of those, 30 were given a high dose of psilocybin and a daily placebo, while the others were given daily escitalopram and a dose of psilocybin so low that it was unlikely to have an effect.

Both groups went through two sessions, in which they were given the drugs and played a curated music playlist, while being guided by a psychological support team.

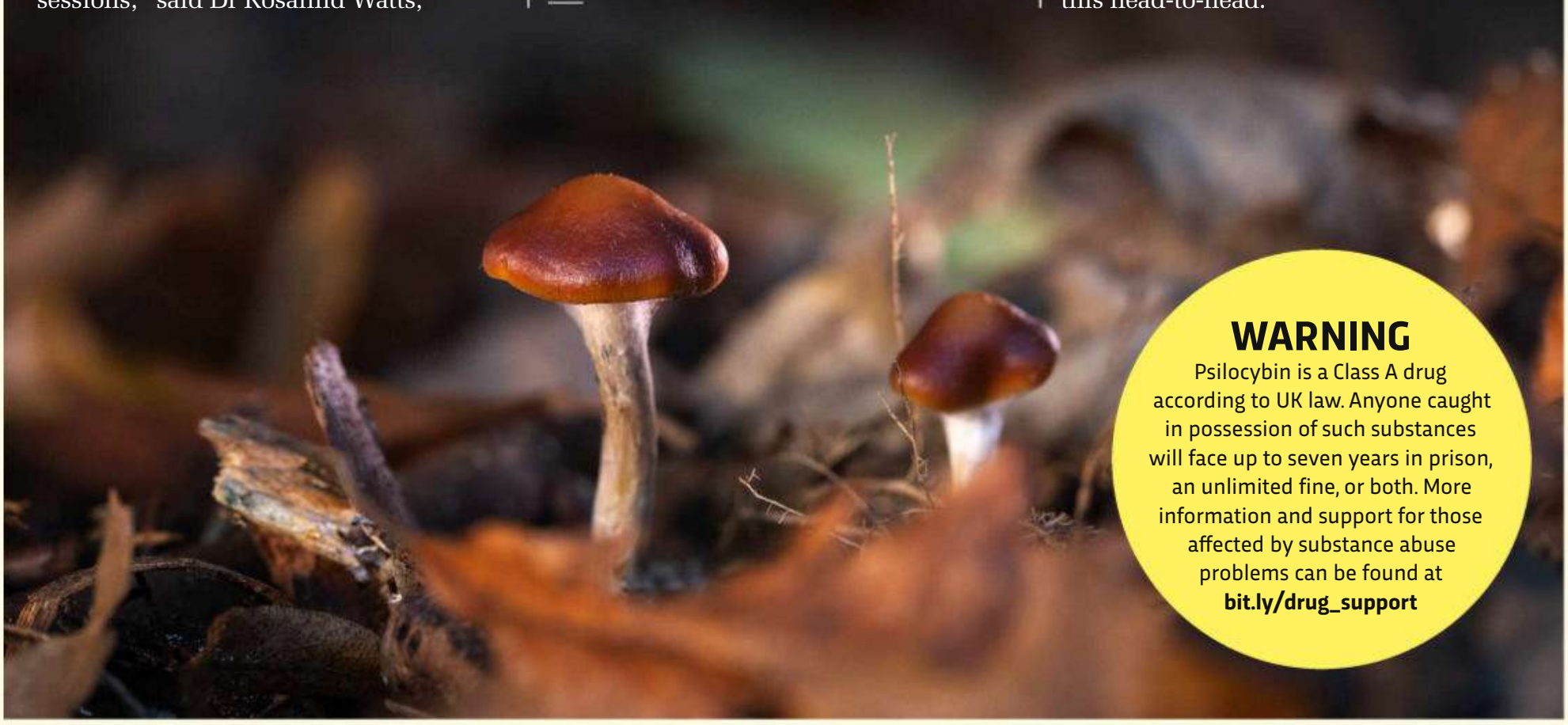
"Context is crucial for these studies and all volunteers received therapy during and after their psilocybin sessions," said Dr Rosalind Watts, clinical lead of the trial. "Our team of therapists were on hand to offer full support through sometimes difficult emotional experiences."

All participants were assessed using a standard depression score which grades sleep, feelings of sadness, appetite and suicide ideation. The team did not find a statistically significant difference between the two groups in terms of how their depression scores changed over the six weeks. However, they also looked at two additional measures at an individual level: response and remission. Response is defined as when a person's depression score reduces by at least 50 per cent; 70 per cent of people in the psilocybin group met this requirement, whereas only 48 per cent of the people in the antidepressant group did. They also found that 57 per cent of the psilocybin group were in remission at the end of the study, compared to 28 per cent in the antidepressant group.

> "People can clearly see the promise of properly delivered psilocybin therapy"

"These results comparing two doses of psilocybin therapy with 43 daily doses of one of the best performing SSRI antidepressants help contextualise psilocybin's promise as a potential mental health treatment. Remission rates were twice as high in the psilocybin group than the escitalopram group," said Dr Robin Carhart-Harris, head of the Centre for Psychedelic Research at Imperial, who designed and led the study.

"One of the most important aspects of this work is that people can clearly see the promise of properly delivered psilocybin therapy by viewing it compared with a more familiar, established treatment in the same study. Psilocybin performed very favourably in this head-to-head."

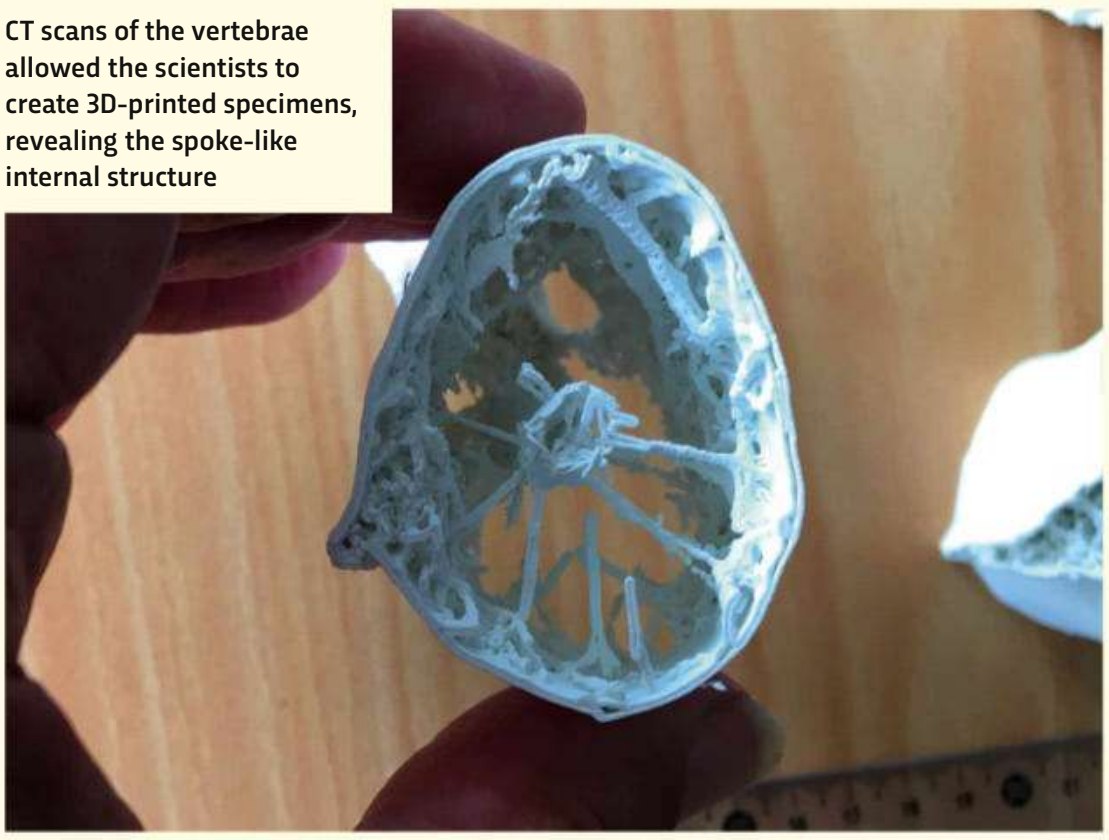


WARNING

Psilocybin is a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both. More information and support for those affected by substance abuse problems can be found at **bit.ly/drug_support**

DAVIDE BONADONNA/CELL PRESS, WILLIAMS ET AL, IMPERIAL COLLEGE LONDON/THOMAS ANGUS

Pterosaurs had strong, lightweight vertebrae



CT scans of the vertebrae allowed the scientists to create 3D-printed specimens, revealing the spoke-like internal structure

ANCIENT LIFE

Mystery of the pterosaurs and their ridiculously long necks is finally solved

Unless they're keeping it very well hidden, giraffes aren't known for their flying prowess. However, extinct azhdarchid pterosaurs, gigantic reptiles with long necks and even larger heads, were able to take to the air. Yet exactly how the animals managed to fly has been a long-standing mystery. Despite these pterosaurs having a wingspan of up to 12 metres, palaeobiologists have wondered how this close cousin of the dinosaurs could be lightweight enough to fly, while also having bones strong enough to support their 2.5m-long necks.

A new study, which was published in the journal *iScience*, may have finally solved the puzzle. While researchers previously presumed the bones in a pterosaur's neck had a simple tube-within-a-tube structure, CT scans of pterosaur bones revealed their vertebrae had a unique internal construction mirroring the spokes of a bicycle wheel.

Scans showed the bones contain a number of thin rod-like tissues (known as trabeculae) that are arranged in the shape of a corkscrew – and even cross over each other. This strong and lightweight network of trabeculae explains how the pterosaurs could fly and move their massive 1.5m-long heads without snapping their necks (which are described as "ridiculously long" by study first author Cariad Williams, PhD student at the University of Illinois at Urbana-Champaign).

In fact, further analysis revealed that as few as 50 spoke-like trabeculae could increase the amount of weight their necks could carry without buckling by 90 per cent.

"What was utterly remarkable was that the internal structure was perfectly preserved," said study co-author Prof David Martill. "As soon as we saw the intricate pattern of radial trabeculae, we realised there was something special going on. As we looked closer, we could see that they were arranged in a helix travelling up and down the vertebral tube and crossing each other."

While existing at the same time, pterosaurs are not classified as dinosaurs, as they evolved on a separate branch of the reptile family tree. The pterosaurs first appeared during the Triassic Period, 215 million years ago, and thrived for an estimated 150 million years before going extinct alongside the majority of dinosaurs.

They did what?

Miniature replica of Vincent van Gogh's *The Starry Night* created using a 'laser paintbrush'

WHAT DID THEY DO?
Researchers at ITMO University in Russia have 'painted' a 5 x 8cm replica of Vincent van Gogh's famous 1889 masterpiece *The Starry Night* onto a metallic canvas using a laser.

HOW DID THEY DO IT?
The metal was heated with a laser to its oxidation point to form an oxide film. The colourful effect of the painting was due to the interference of two waves – one reflecting from the top of the thin oxide film on the surface of the metal and one from the metal surface itself. By varying the time that the oxidation of the metal occurred, they could control the thickness of the film, therefore allowing them to create different wavelengths and so different colours of light.

WHY DID THEY DO THAT?
The researchers are now working on a handheld version of the technology and hope that it will be used by modern artists to create new forms of art.

COMPUTERS

Scientists train a computer to learn like a human

In a now-famous experiment, Russian physiologist Ivan Pavlov taught his dog to associate food with the sound of a bell ringing, so much so that the dog would start to drool when it heard the sound. This was a demonstration of 'associative learning': how our experiences and memories can lead to unrelated ideas being linked in our brains over time.

Now, a team of researchers at Northwestern University and the University of Hong Kong have developed a device that can learn over time in the same way, mimicking a human brain. This technology could be more energy-efficient than traditional computers, the scientists say, and can even continue to run smoothly when some components fail.

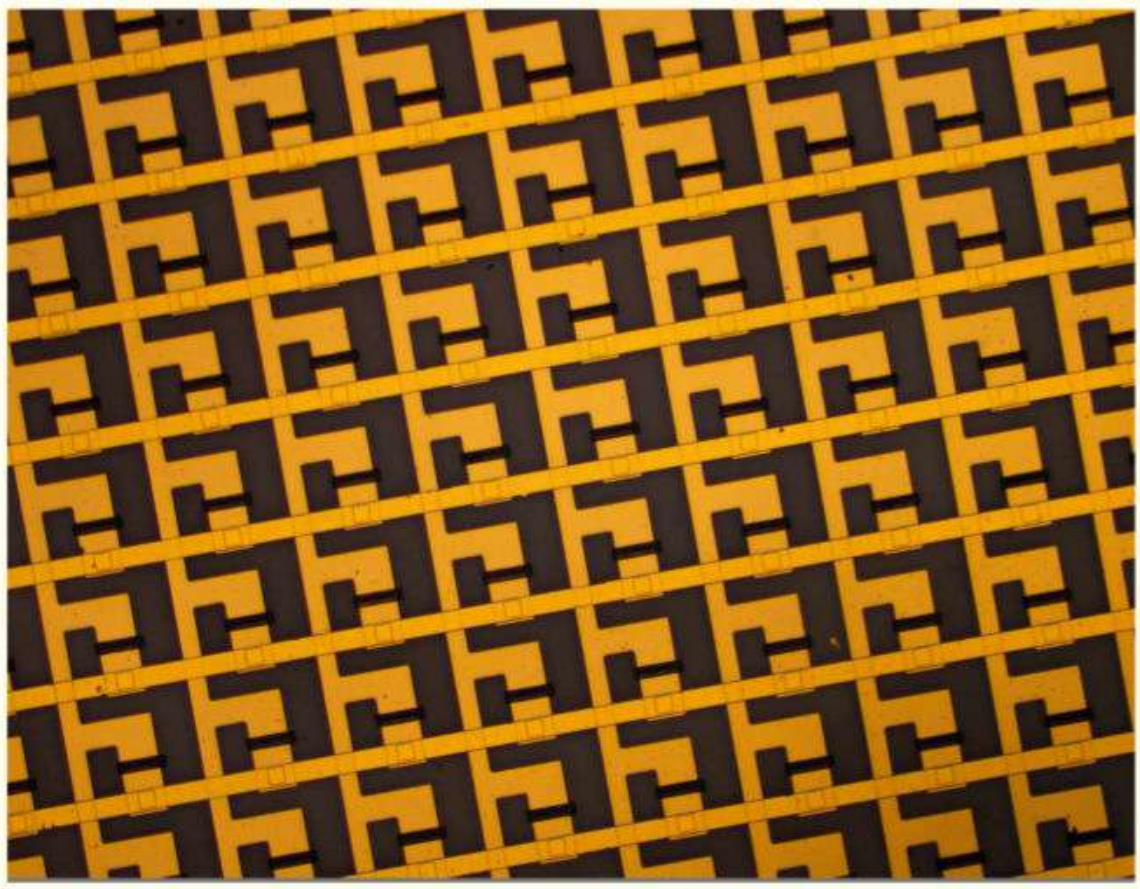
The brain has synapses that connect neurons together and pass messages between them using chemicals called neurotransmitters. Strengthening the connection between two neurons results in the creation of memory.

Inspired by this process, the team developed the 'synaptic transistor', an organic, electrochemical device that can trap ions. The ions behave like neurotransmitters, and trapping them allows the transistor to 'remember' previous activity. This process lets the device form connections over time.

The team conditioned the device to associate light with pressure. First, they pulsed an LED light bulb, which the device picked up with its light sensors, and they immediately followed that by applying pressure to its pressure sensors. After several training cycles, the circuit had formed a significant association between light and pressure. It started to produce a signal corresponding with pressure after only a flash of light.

"Although the modern computer is outstanding, the human brain can easily outperform it in some complex and unstructured tasks, such as pattern recognition, motor control and multisensory integration," said Dr Jonathan Rivnay, assistant professor of biomedical engineering at Northwestern University and a senior author of the study.

"This is thanks to the plasticity of the synapse, which is the basic building block of the brain's computational power. These synapses enable the brain to work in a highly parallel, fault-tolerant and energy-efficient manner."



Each square is a single synaptic transistor. Many of them were connected up to form a brain-like circuit

RUB/MARQUARD, NORTHWESTERN UNIVERSITY ILLUSTRATION: KYLE SMART

Nothing says “we care” like having your counsellor swapped for a handsy robot

Future counsellor robots could comfort humans with a simple pat on the hand

Do you think that a robot could be persuasive in any way? You might, after it gives you a comforting pat on the hand. At least, that’s the finding of an intriguing new study that looked at how an android’s physical touch can impact humans.

In the study, which was carried out by researchers from Germany’s University of Duisburg-Essen, 48 students engaged in a one-on-one school counselling conversation with a humanoid robot (Softbank Robotics’ NAO). While the robot simply moved its hand towards some of the participants (the control group), for others it physically patted their hand three times in a ‘touch-release’ action. Interestingly, the scientists noted that while the majority of participants smiled and even laughed at this movement – particularly if performed at the end of the conversation – none of them pulled away from the robot.

Compared to the control group, the touched students reported higher levels of emotional wellbeing (as measured by a post-experiment questionnaire). They also showed more interest in a specific academic course suggested by the robot during the conversation.

Students who were patted were more likely to give the robot a marginally higher score for physical attractiveness (although these participants still only rated poor NOA a 2.5 out of 5 on average).

“A robot’s non-functional touch matters to humans. Slightly tapping human participants’ hands during a conversation resulted in better feelings and more compliance to the request of a humanoid robot,” said the paper’s authors Dr Laura Hoffmann and Prof Nicole Krämer.

“It is furthermore remarkable that simply tapping the back of participants’ hands showed such an effect. Involving more complex and prolonged touching from a robot might increase engagement and compliance.”

As the researchers argue, this small study – one of the first to examine the impact of robot-initiated touch – suggests that through the use of comforting touches, robot counsellors could better persuade patients to engage in healthy activities such as exercise.

However, they caution that much about human-robot interactions are complex, with still more to be learned about the difference between human and robot touch.

SILVER SURFERS

People aged 55 to 75 who used the internet more over lockdown, particularly for staying in touch with friends and family, were at lower risk of depression and reported a higher quality of life, a study carried out at the University of Surrey has found.

THE YOUNG AT HEART

Middle-aged and older adults who feel younger have a greater sense of wellbeing, better cognitive functioning, less inflammation, lower risk of hospitalisation and live longer than their older-feeling peers, a study at the German Centre for Gerontology has found.

Good month

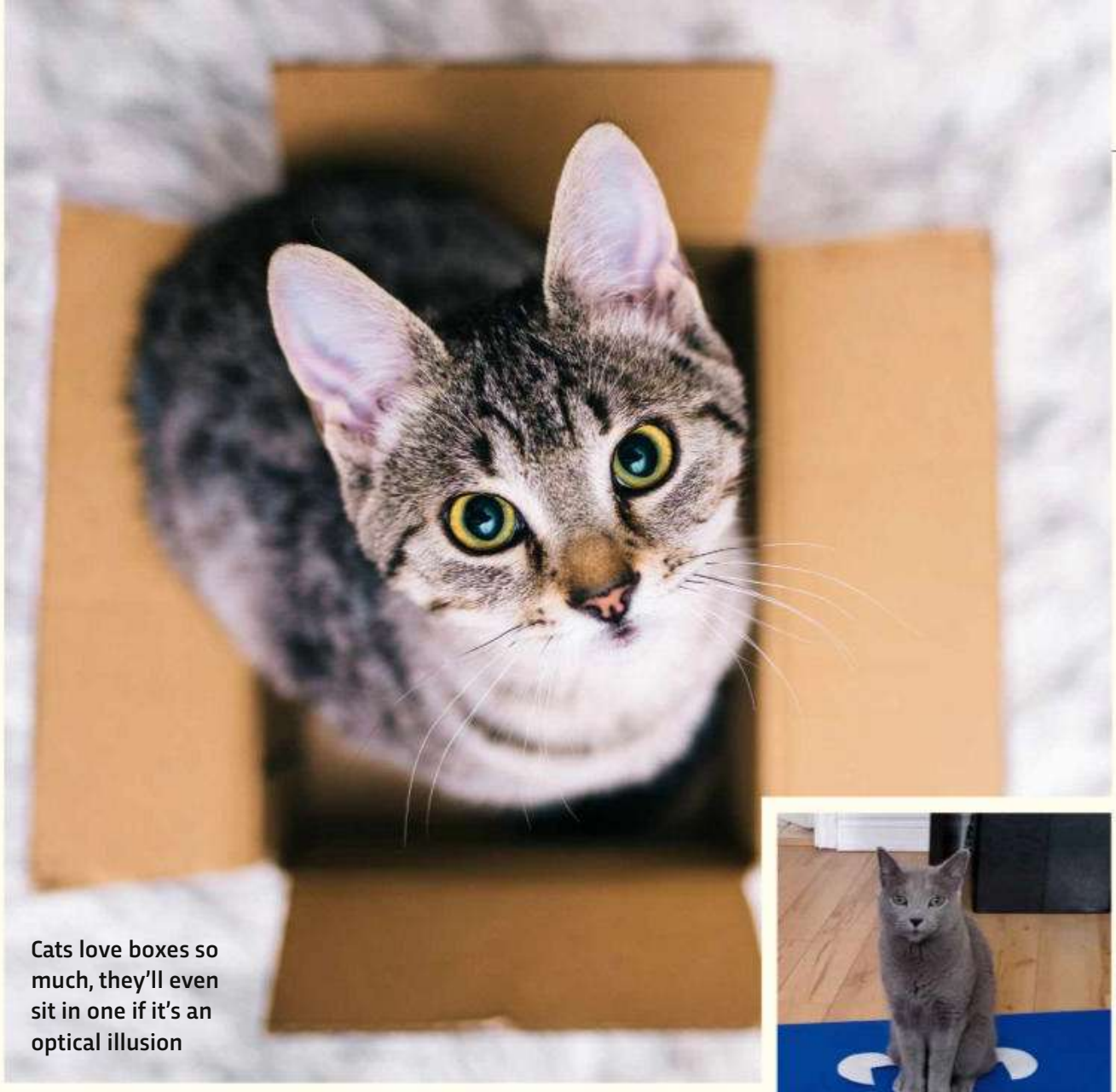
Bad month

CITY-SLICKERS

Urban dwellers are more likely to exhibit the 'dark triad' traits – psychopathy, narcissism and Machiavellianism – researchers at the University of Derby have found.

OPEN-PLAN OFFICE WORKERS

Office workers with a large number of desks in their field of vision are less likely to rate their workplace favourably, a study carried out at The Bartlett School of Architecture has found. The effect is possibly due to the extra distractions and difficulty talking to co-workers without disturbing others, they say.



Cats love boxes so much, they'll even sit in one if it's an optical illusion

ANIMALS

The 'if I fits, I sits' instinct: cats will sit in a box even it's an optical illusion

Cats love boxes. It's thought that this behaviour is driven by animal instinct: as ambush predators, they're attracted to confined places where they can hide, observe prey and feel safe.

The calming effect of this curious habit was proven in 2014, when a study carried out at the University of Utrecht in the Netherlands found that shelter cats provided with boxes to hide in recovered more quickly and adapted to their new environments more comfortably than their box-less buddies.

Now, a citizen science project led by researchers at City University of New York has found that this behaviour is so ingrained in moggies that they are even drawn to sit in square shapes created by optical illusions.

The researchers asked cat owners to set up different shapes on their living room floors to see if the cats were compelled to sit in them. Some simply made a square out of tape on the floor, while others set up an optical illusion known as the Kanizsa square – an arrangement of four Pac-Man-like shapes positioned to look as if they are forming the four corners of a square.

The Kanizsa shapes trigger the perception of an actual square existing by tricking our brains to fill in the missing information. The cat owners also set-up Kanizsa control patterns in which the Pac-Man shapes were reversed so no optical illusion was created.

The researchers then asked the owners to record their cats' behaviour over six days.

"The cats in this study stood or sat in the Kanizsa and square stimuli more often than the Kanizsa control, revealing susceptibility to illusory contours and supporting our hypothesis that cats treat an illusory square as they do a real square," the researchers said.

The team say that the trial is limited by its small sample size; of the original 561 cat owners that signed up, just 30 made it all the way through the study. Still, the findings confirm pre-existing research of cats' susceptibility to optical illusions.

GETTY IMAGES X2, GABRIELLA SMITH ILLUSTRATION: KYLE SMART

DERMATOLOGY

Feeling itchy? Sensor detects scratching to tell doctors how bad eczema is

The device could be used to develop drugs and other treatments for skin conditions

Atopic dermatitis, or eczema, is a common skin condition affecting around one in five children. It can cause sufferers to itch so badly that they stay awake at night scratching, causing them to lose, on average, a full night's sleep per week.

Itching, however, is a difficult symptom to measure, making it tricky to track how effective any drugs and treatments being administered are. Now, though, researchers at Northwestern University have developed a soft skin patch capable of measuring how often its wearer scratches themself.

The patch consists of a soft, flexible sensor that fits around the patient's hand and is linked up to machine learning algorithms that specifically identify scratching without being tricked by similar motion-related movements such as hand waving. It is the first sensor that is capable of capturing all forms of scratching, whether the movement comes from the finger, wrist or elbow.

"Atopic dermatitis is so much more than just itchy skin. It is a devastating disease that causes tremendous suffering worldwide. The quality of life of severe atopic dermatitis – not only for the child but also the parent – is equivalent to many life-threatening diseases," said lead author Dr Shuai 'Steve' Xu, assistant professor of dermatology and of paediatrics at Northwestern University Feinberg School of Medicine. "Patients with atopic dermatitis are 44 per cent more likely to report suicidal thoughts as a result of the itch compared to controls. Thus, the ability to quantify their symptoms is really important to help new drugs get approved, but also support their day to day lives. In some ways, it's like measuring glucose for diabetes ... measuring itching in an atopic dermatitis patient may be just as important."

The study was conducted in two parts. The first part involved training the wearable sensor to pick up scratching in healthy adults doing voluntary scratching behaviours. The second part of the study then tested the sensors on children with atopic dermatitis, logging more than 300 hours of sleep data.

"This is an exciting time for children and adults with atopic dermatitis – or eczema – because of the flurry of activity in developing new therapeutics," said Dr Amy Paller, chair of dermatology at Northwestern. "Nothing is more important to measure a medication's effectiveness for eczema than itch, the symptom that both defines eczema and has the greatest impact on quality of life. This sensor could play a critical role in this regard, especially for children."

A new sensor can measure how often someone scratches, which could help in the development of new treatments for itchy skin conditions like eczema

CHRISTIAN CLOT
Explorer, researcher, author

Horizons

Could you cope without natural light for 40 days?

The Deep Time project saw 15 volunteers sign up to spend over month in a cave beneath the Pyrenees with no access to natural light or clocks. Most of them want to go back...

FIRST OFF, WHY DID YOU WANT TO DO THIS?

Our main aim is to study adaptation – how we adapt to new situations, new environments or events. Being in the UK or France, we're used to having an easy life, in a way. We have less knowledge about how we can suddenly change our way of doing things. We saw that with COVID-19, of course – suddenly we had to change a lot of things. It was hard for a lot of people. Many people were completely lost in this situation and some even lost track of time. People were telling us, "I don't remember if I have to eat or if I've already eaten, or what I have to do tomorrow."

I figured that we had to build an experiment to study this sense of time. the Deep Time project is the result – putting some people in a cave with no outside contact. No sunlight, no clocks.

DID YOU KNOW WHAT MIGHT HAPPEN?

Yeah, we had some information from similar experiments, mainly by Michel Siffre in the 1960s and 1970s in France. We knew that we'd experience some change of time.

But we also had information from experiments like Mars-500 [an experiment that simulated the isolation of a long-term space mission]. But the participants in that knew it was a simulation, so it became like a game – a puzzle you try to solve and not something that makes you think, "Okay, if I had to live here for my whole life, what would I do?" That's why we came up with the idea of going into a cave.

WHAT WERE THE FIRST FEW DAYS LIKE?

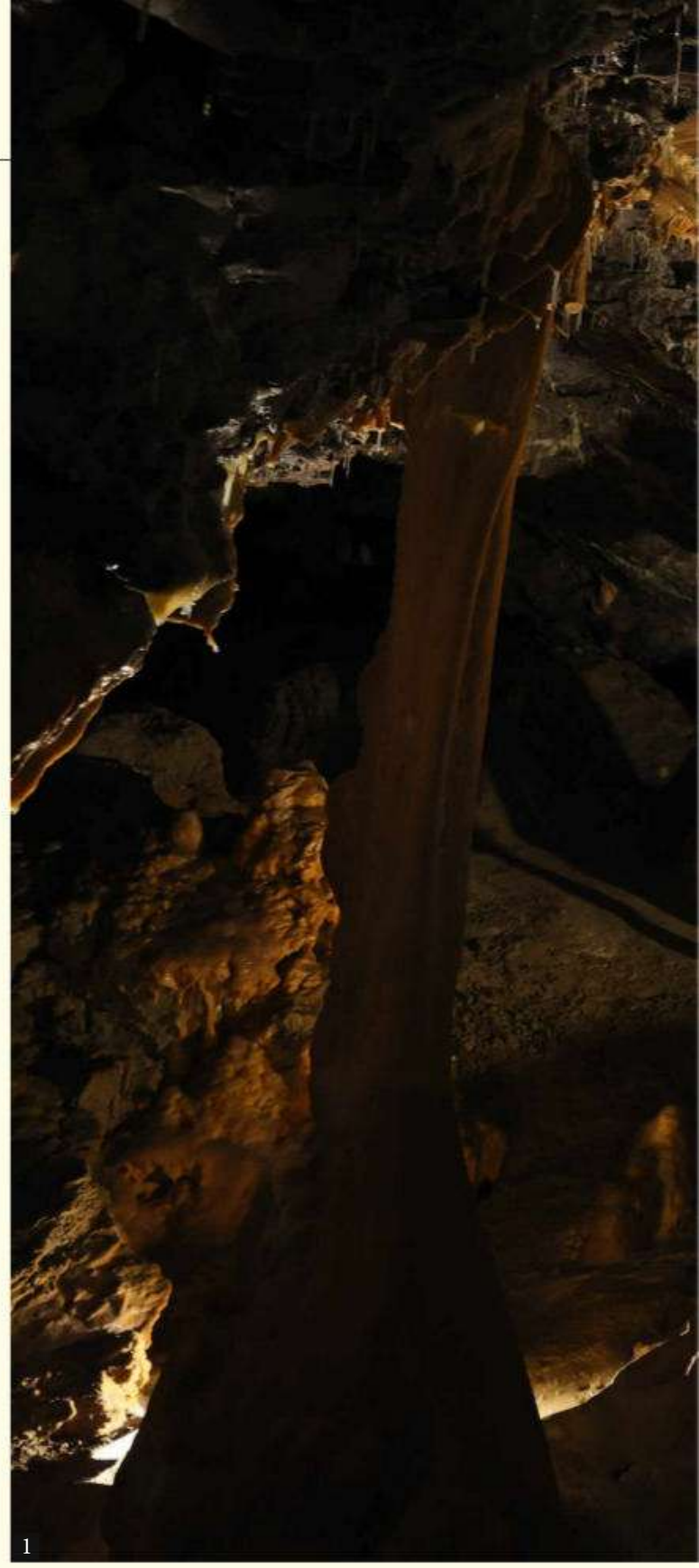
The first night was really disturbing. You'd wake up suddenly, but you wouldn't be able to tell if it was the middle of the night. Usually when you wake up, the first thing you do is check to see what time it is. But we didn't have any phones, clocks or any way to see the Sun. It was impossible to know how long you'd slept. So, you'd just have to accept that there's no point trying to understand time.

After about seven days, we decided we had to figure out some goals and work together more to change the way we organised our time. After doing that, it got much easier.

WERE YOU SURPRISED BY HOW QUICKLY THE GROUP WAS ABLE TO ADAPT?

Yeah, totally. I read everything about the experiments in the 1960s and 1970s and the people in those really struggled. So I was really afraid.

A group is the best system to help people adapt to difficult situations, and diversity is important. I built our group with normal people that were all from different social systems and different places in France. If there was problem or something happened, someone always had a solution to offer. I mean,



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BRUNOMAZODIER/HUMAN ADAPTATION INSTITUTE/DEEPTIME X2

1. Exploring the grotto
Developing a working knowledge of the tunnels and caverns that formed the group's surroundings was a vital task. Exploratory expeditions were undertaken frequently during their stay in the temporary subterranean home.

2. Reuniting at camp
Mealtimes were a chance for the entire group to get together and socialise, as well as discuss any issues. Without a way to tell the time, it's unclear if the meals were at regular intervals, but eating together at agreed points may have provided some sense of routine and helped synchronise the group.

each time I had an argument, half an hour later, it was resolved – that's much quicker than in my normal life.

DID YOUR SLEEP CYCLES SYNCHRONISE?

Yes, in a way. We all had our own rhythm. Some were sleeping a lot and others were sleeping only a few hours. But after a while we felt that it was normal. I thought we must be running on 24- or 25-hour days. But at the end of the experiment, when people came to retrieve us, it was a shock. We thought we had been in the cave for 30 days, but we'd been in for 40. I couldn't understand how it was possible. Obviously, we had a completely different rhythm to the outside world. And it's something that I don't think has been observed before. We'll have to analyse what happened and repeat the experience to understand why we had such a huge difference between our time and normal time. But it seems as if ➲

1

2

our biology didn't determine our rhythm, it was our need to spend time together.

HOW DID IT FEEL TO BE FREE FROM CLOCKS?

Towards the end we were never thinking, "Oh that went quickly" or "this is taking too long". We were always taking the right amount of time, because there was no clock to compare to. That was a new sensation. I feel – and I know my colleagues feel the same – that I was much more free in the cave because I didn't have to follow time.

HOW CAN YOU BRING THAT LEARNING BACK INTO THE REAL WORLD?

I try to put my phone away as much as I can now. I really feel like we have to change something in our lives. I saw these people in such an uncomfortable situation, but they were happy. Of course, we can't all go and live in a cave. But I think we need to think deeply about what our time is and what we do with it.

WHAT DATA DID YOU COLLECT?

We had three kinds of data. The first was biological – we measured the temperature in the cave and gathered blood and tissue samples. We also tracked our sleep. The second was to do with cognition. We had tests to probe perception, decision-making and so on. We also used EEGs to measure brain activity and we all went for MRI scans before and after the expedition.

The third area we looked at was emotions and how they evolved during the expedition. I think these are really important when it comes to making decisions. We used skin sensors to test sweat response and heart sensors to spot if someone's heart rate was elevated. But these don't tell us a lot, so we ran a lot of questionnaires to find out how people were feeling over the course of the 40 days underground.

There was a fourth factor, which was the cave itself. I chose a cave because it gave a sense of wonder. I'm sure that beauty – that feeling when you're excited to see and interact with your environment – is important when we talk about people being able to adapt.

I SUPPOSE THAT'S WHAT OTHER MISSIONS HAVE LACKED – A SENSE OF ADVENTURE

I saw it in the eyes of each of the volunteers. There was a second level to the cave. We had to abseil down to this lake with a little boat in it. It was beautiful. I could see when they came back afterwards that they felt so happy. They had a reason to be here – this idea of wonder. If you have something that makes you happy, then it's a strong reason to get up and fight, even if the situation is hard.

"We thought we had been in the cave for 30 days, but we'd been in for 40. I couldn't understand how it was possible."

BRUNOMAZODIER/HUMAN ADAPTATION INSTITUTE/DEEPTIME X4

WHAT'S THE NEXT PHASE?

So we have at least 12 teams working on the data right now. And of course, we want to do another Deep Time experiment, just to check if we see the same thing happening or if it's completely different.

In 2022, we'll go in a rainforest or desert to see if it's the environment that's the strongest factor causing groups to adapt, or if people adapt in the same way whatever the environment is, or if the environment has an effect. And hopefully we'll see how they, and their brains, adapt.

3

4

1. Eat when you're hungry or when everyone else is?
Shared mealtimes appeared to be important to the Deep Time volunteers, even when some members were away from the main group during expeditions into the cave system.

2. A sense of wonder
Christian Clot wanted to expose the Deep Time group to a real, natural environment rather than a simulated habitat. Such a place would have a greater potential for inducing a sense of wonder in the volunteers, similar to what astronauts might experience while travelling through space or landing on another planet. The cathedral-like spaces in the cave certainly fit the bill.

3. Tight squeeze
Adjusting to the group's new environment brought all manner of unexpected challenges. Even apparently simple tasks such as travelling from one spot to another required a degree of adaptation – especially when you can't always walk upright.

4. Lab work
Getting an insight into how the volunteers were adjusting to life underground was a complicated process. As well as questionnaires to gauge mood, decision making and emotional disposition, physical tests were also undertaken. Here, two of the volunteers ride exercise bikes while another pair monitor the riders' heart rates, sweat levels and a range of other biomarkers.

CHRISTIAN CLOT
Christian is an explorer, researcher and author, who heads up the Human Adaptation Institute. He led the Deep Time experiment. ***Interviewed by*** **BBC Science Focus** ***editor Daniel Bennett.***

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Microplastics | Climate crisis | BMI

REVIEW

MICROPLASTICS: ARE THEY HARMING ME, AND CAN I DO ANYTHING ABOUT IT?

Tiny plastic fragments are found in every environment on Earth, even those with no human inhabitants. Dr Stephanie Wright, who studies toxicology in the environment, explains the dangers

“Up to 1.5 million microfibres can be released per kilo of clothing during a wash. Even opening a plastic bottle or plastic packet can create thousands of microplastics”

BBC *Visit the BBC’s* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHAT ARE MICROPLASTICS?

Plastic is a solid, synthetic material made from oil and gas, or renewable organic material from plants. It is the third most abundant material after concrete and steel, and is hugely important for society due to its uses in many different sectors, including medicine, construction, food packaging, electronics and transport. Microplastics are microscopic pieces of plastic debris. You need the help of a microscope to see most of them, although the formal definition includes plastic particles up to half a centimetre – big enough to see with the naked eye.

WHERE DO THEY COME FROM?

Many different places. Microplastics shed from plastic litter due to sunlight exposure, which causes the material to weaken over time and fragment. They’ll also come from plastic items because of wear and tear. Due to the wide range of plastics, applications and forms, microplastics are found in a variety of shapes and types. In fact, up to 1.5 million microfibres, which are a microplastic, can be released per kilogram of clothing during a wash. Even opening a plastic bottle or plastic packet can create thousands of microplastics.

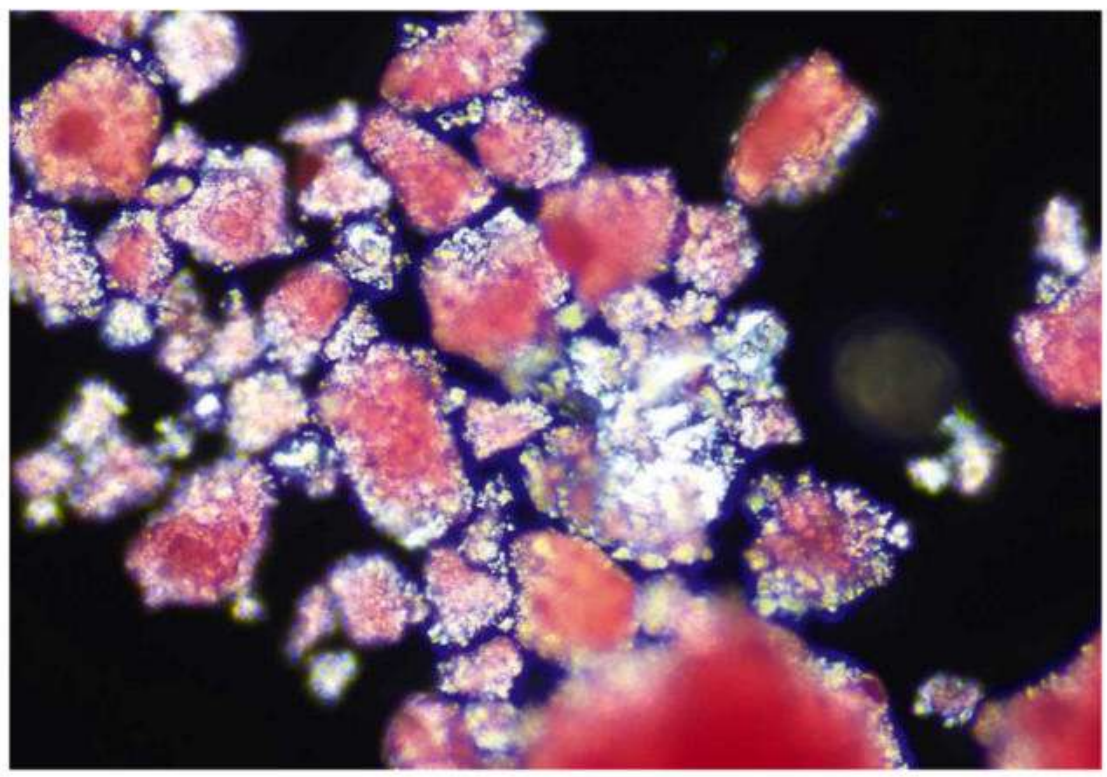
Microplastics move throughout the environment via both human and natural processes. For example, the microplastic fibres released from your clothes during laundering are rinsed down the drain where between 72 to 94 per cent is captured in sewage sludge during wastewater treatment. This sludge is then applied to the land as an important soil conditioner. Winds can mobilise the soil in dry conditions, potentially blowing the microplastics away. This can also happen to microplastics polluting roads, cities and the surface of the oceans, distributing them far and wide. The complexity of microplastics’ sources and journey as they cycle through the Earth’s environments means they are incredibly challenging for both scientists and environmental managers to study.

HOW WIDESPREAD ARE THEY?

Over the last few decades, the evidence on the extent of microplastic pollution has been growing. Originally perceived as a marine issue, with an estimated 15 to 51 trillion microplastic particles floating on the ocean’s surface, scientists have recently discovered they also contaminate rivers, soils and air. They have even found their way into some of the most remote regions, including the poles, the equator, the deep ocean floor and even Mount Everest.

ARE HUMANS INGESTING THEM, AND IF SO AT WHAT RATE?

The short answer is: yes, with the discovery of microplastics in human stool confirming this. Microplastics have been found in a range of food and drinks, mostly bottled and tap water, shellfish and salt. They’ve also been measured in indoor dust, which may settle on our food and drinks. Current high-end estimates of the rate of ingestion range from 52,000 to billions of microplastics per year. However, the food ➲



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BELOW Microplastic particles are tiny, with some of them only becoming visible under a microscope

groups investigated by most researchers represent a very small amount of the average adult's diet. There are many food types which we consume a lot of that haven't been investigated yet, such as cereals, and so it is hard to get a clear picture of exactly how many microplastics we are consuming.

ARE THEY HARMFUL?

There currently isn't enough evidence to say, because this is a relatively new topic and researchers are still building the evidence base. It is plausible that microplastics cause harm, as other particles can do, but the differences between the nature of microplastics compared to these particles leaves uncertainty. There is some experimental evidence emerging to suggest that ingestion of high levels of polystyrene beads affects the reproductive system in rats and mice, but what is causing this and how relevant this is to real-life microplastic exposures is unknown. It's likely that the very smallest particles have the greatest potential to cause harm, but quantifying these and understanding where they come from is a challenge.

WHAT CAN WE DO TO LIMIT OUR EXPOSURE?

While the debate is still ongoing as to whether microplastic could cause harm, you may still wish to limit your exposure. Drinking filtered tap water and choosing natural-based products over plastic for yourself and your environment will help to reduce your microplastic exposure.

Ultimately, minimising everyone's exposure requires a global effort to limit microplastic release to the environment. Things you could do to contribute to this include avoiding single-use plastic while shopping (and bringing your own bag); reducing your plastic waste; washing your clothes less often and using a laundry bag to catch some of the fibres which go down the drain. When in doubt, I try to stick by the '5 Rs': refuse, reduce, reuse, repurpose and finally, recycle. Whatever the solution, it's important that it's better for both the planet and people.

by **DR STEPHANIE WRIGHT**

Stephanie is a lecturer at the Medical Research Council. She has more than nine years' experience in the field of microplastics, specifically exposure and biological impacts.

ANALYSIS

CLIMATE CHANGE: CAN THE NEW TARGETS GET US TO NET ZERO?

The UK government is aiming for an emissions cut of 78 per cent, compared with levels in 1990. They want to achieve this by 2035. Is this feasible?

The government has announced an ambitious new climate target by 2035 which will bring the UK more than three-quarters of the way towards its goal to reach climate neutrality.

Announced in April, the target aims for a country-wide emissions cut of 78 per cent by 2035, compared to 1990 levels. It will set the UK on track to

meet its long-term goal to reach 'net-zero' emissions by 2050.

For the first time, the target also incorporates the UK's share of international aviation and shipping emissions, which will require a 'transformation' of these sectors, campaigners say.

"This bold new target places the UK at the forefront of climate pledges and is a significant step up in ambition from just a few years ago," says Jess Ralston, analyst at the Energy and Climate Intelligence Unit (ECIU). "With long term and determined policy support there's no reason why we can't seize this huge opportunity to slash emissions while growing our green economy."

ABOVE For the first time, the UK will be including aviation and shipping industries in its emissions targets, which will require a huge overhaul of these sectors

GETTY IMAGES

THE TARGET

The UK's Climate Change Act requires the government to set legally binding climate targets every five years. These set the direction of travel for government and business, says Katie White, executive director of advocacy and campaigns at WWF, and allow successive governments to be held to account should they fail to make progress.

In December, the government's independent climate advisors recommended a new target to cut emissions by 78 per cent by 2035, including international aviation and shipping. The government has now accepted this advice, with the new target set to become law in late June.

Chris Stark, chief executive of the Committee on Climate Change (CCC), said in a statement he was "delighted" the government had accepted his organisation's advice. "By implementing our recommendations in full, the government's decision rests on the most comprehensive ever assessment of the path to a fully decarbonised economy," he said. "It means that every choice we make from now must be the right one for our climate."

The new target is also seen as a bid for UK climate leadership ahead of the major COP26 climate summit, set to be hosted in Glasgow this November. Announcing the target, Prime Minister Boris Johnson said the UK wants to "raise the bar" on tackling climate change and see world leaders "follow our lead".

"[The target] will speed up the rate of emissions reduction over the next decade, which is crucial if we're to limit the global temperature rise to 1.5°C," says Sam Hall, director of the Conservative Environment Network. "It will also drive more investment into clean technologies and green infrastructure in the next few years, which will help stimulate the economy and create jobs as we emerge from the COVID pandemic."

The inclusion of aviation and shipping in the climate target was a particularly significant step, says Cait Hewitt, deputy director of the Aviation Environment Federation (AEF). "We're the first major economy to include these emissions in our climate law."

However, the CCC has previously warned that the UK is not on track to meet its two earlier climate targets for 2025 and 2030. Reacting to the news of the 2035 target, Labour MP Ed Miliband, former climate change secretary under Labour and now shadow business secretary, said in a statement that the government "can't be trusted" to match rhetoric with reality. "The character of this government on climate change is now clear: targets without delivery," he said.

WHAT'S NEXT

The challenge for the government now is to set out how it plans to meet these targets and start putting policies into place.

The UK has seen significant reduction in its carbon emissions over the past decade, with emissions 45 per cent below 1990 levels in 2019 and 49 per cent below 1990 levels in 2020, according to government figures.

The majority of these emissions cuts have occurred through the decarbonisation of the electricity system, as coal plants were shut down and renewables steeply

Renewable energy, like wind power, expanded in the UK following the closure of many coal-fired plants

expanded. But the new 2035 target will require active changes in other areas which have lagged behind on emissions cuts, such as home heating and transport.

Reducing emissions in these sectors may need more proactive decisions from consumers to reduce their carbon footprints, says Ralston. It will also create a huge number of jobs. A recent analysis found some 500,000 new green jobs could be created in England alone by 2030 if it takes the action needed to reach its climate goals.

Meanwhile, the government is expected to publish its aviation net zero consultation before the summer break, says Hewitt. AEF is hoping to see new policies to tackle aviation emissions, such as annual emissions targets for airlines, a review of policy on airport expansions or financial measures such as an air miles tax.

The UK is among a host of countries to set net zero climate targets in recent years, as countries strive to implement the Paris Agreement and show they are taking climate change seriously. With the COP26 conference set to take place in just six months' time (bar any delay due to COVID), the pressure on the UK to show further leadership to implement its targets is only likely to increase further.

by **JOCELYN TIMPERLEY**

Jocelyn is a journalist who focuses on the climate crisis, writing for the likes of the BBC, Carbon Brief and Energy Monitor.

COMMENT

BMI: IT'S FLAWED, SO WHY DO WE USE IT?

A report published by the Women and Equalities Committee says that the use of the Body Mass Index should be scrapped. Is there a better way to calculate if you're a healthy weight?

Barely a day goes by without a news piece or television documentary breathlessly reporting on the current pandemic of obesity. Nearly 60 per cent of us in the UK and US are either overweight or living with obesity. Where does this ominous 60 per cent figure originate from? Well, it has emerged from population-wide BMI statistics.

BMI, or Body Mass Index, is the ratio of bodyweight in kilograms divided by the square of one's height in metres, and hence is represented as kg/m^2. A 'normal' BMI is 20-25kg/m^2. Anything below a BMI of 18 would be considered underweight, a BMI of 25-30kg/m^2 is considered overweight, and if you have a BMI north of 30kg/m^2, you would be classed as living with obesity. The reputation of BMI however, has in recent years been tarnished. At best, it's considered a poor proxy for fat mass and health; at its worst, it can and often is used as a cudgel to 'fat-shame' the larger among us in society. But what has BMI done to deserve this, and should it be replaced with anything else?

The problem is that BMI as a measure of 'fatness' is flawed, because it is derived using purely your weight and your height. Thus it cannot, for instance, differentiate between a rugby player and a Joe Public of similar height and weight, but carrying substantially more fat. So why not just measure the amount of fat instead?

The 'gold-standard' method of measuring fat-mass is called dual-energy X-ray absorptiometry or DEXA. This is where two low-power X-ray beams, with differing energy levels, are used to scan your body. X-rays work by differentiating tissue density, so DEXA is able to detect the difference between muscle and bone (which has a higher density) and fat (which has a lower density), and therefore can calculate fat percentage.

Another approach is the use of body-fat scales. These use technology called 'bioelectrical impedance', and function by passing an imperceptible electrical current through your body. As muscle contains more water, it conducts electricity better than fat does; thus the greater the electrical resistance, the more body fat you have.

DEXA is certainly accurate. It is also expensive, requiring specialist equipment and technicians to run,

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“BMI cannot, for instance, differentiate between a rugby player and a Joe Public of similar height and weight, but carrying substantially more fat”

so is not suitable for use in population-wide studies. And the body-fat scales, while widely available, ranging in size and cost from your domestic bathroom scales to large coin-operated weighing machines found in chemists, are notoriously inaccurate.

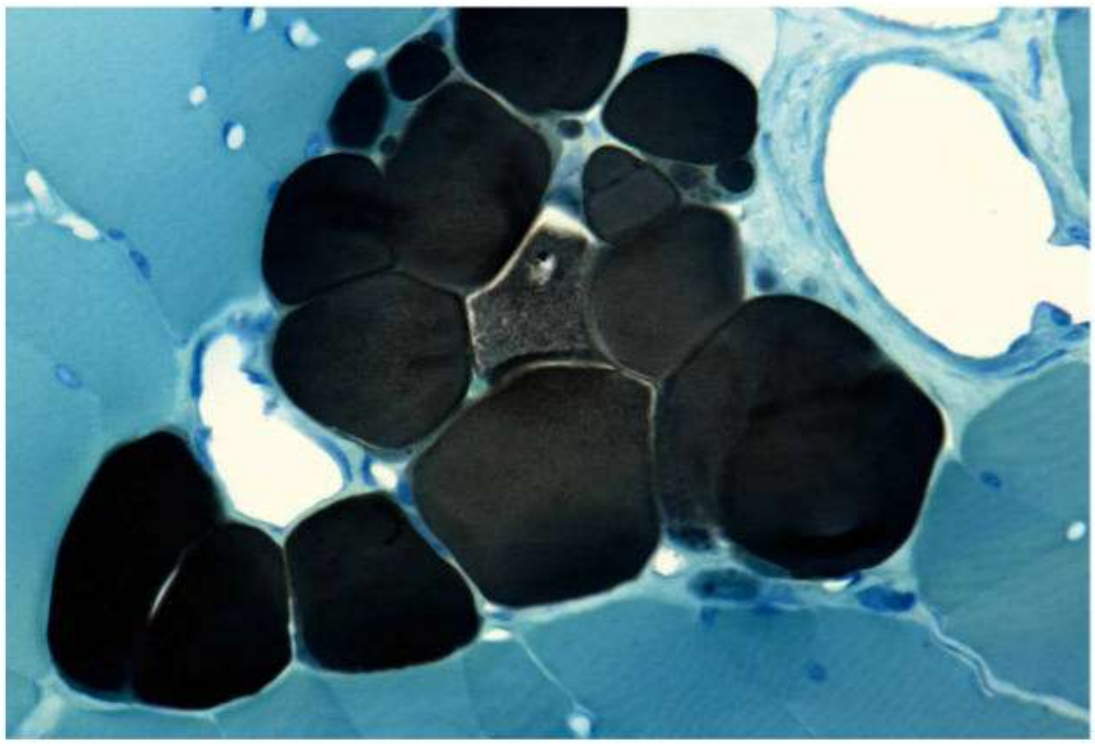
In contrast, BMI is cheap and simple to calculate, and therefore easily scalable. And critically, despite being imperfect for measuring fatness in athletic individuals, the sad fact is the vast majority of the population are not rugby or powerlifter types. As a result, for most of us, the higher our BMI, the more fat we tend to carry, thus BMI is a suitable proxy for tracking weight and health of entire populations.

BMI, however, shouldn’t be used by healthcare professionals, or anyone else, as a be-all and end-all to inform treatment or advice for individual patients. It has to be used in context with other data, such as blood pressure, fasting insulin and glucose levels, as well as family history of metabolic disease. In fact, the UK Parliament’s Women and Equalities Committee recently published a report recommending that the use of BMI in determining if an individual’s weight is healthy should be scrapped, as it contributes to issues such as eating disorders and mental health by disrupting body image and inviting social stigmas.

But why is carrying too much fat bad for you? There is a great deal of misunderstanding of what happens during weight gain or loss, with many thinking that they are gaining or losing fat cells. This isn’t true. Your fat cells are like balloons; they get bigger when you gain weight, and smaller when you lose weight. The actual number of cells doesn’t change by much at all.

Now, the safest place to store fat is in your fat cells. When the cells become full, the fat ends up in places not designed to store fat in large amounts, such as the muscles or liver, and that is when we tilt into diseases such as type 2 diabetes and other metabolic conditions.

So, here is the interesting thing. Depending on our genes, our fat cells, or adipocytes, are able to expand to different sizes before becoming full. So East Asians (such as Chinese folk like me) and South Asians don’t have to put on that much weight before increasing their risk of getting type 2 diabetes. Other ethnicities including white people and, famously, Polynesians for instance, can gain a lot more weight before becoming ill, in large part, due to the expandability of their adipocytes.



ABOVE Fat cells (black) expand like balloons when you gain weight, and shrink down when you lose weight

The degree to which our fat cells can expand is a powerful genetically influenced trait, and informs our differing safe fat-carrying capacities. So in any given population, it is possible to be healthy at many sizes, with some people of higher BMI being the picture of metabolic health, and other lean and fit-looking low-BMI people with type 2 diabetes.

But here is the critical take-home message: for any given individual, there cannot be health at every size, because if you surpass your own personal safe fat-carrying capacity, you WILL become ill.

The $64 million question is, of course, how can we tell what our safe fat-carrying capacity is? Well, figuring this out is the subject of cutting-edge research, and when that happens, we will enter a new era of how we relate fat-mass and bodyweight to health. Until then, the use of BMI as a proxy for ‘fatness’ and hence health, at least at the population level, will continue to dominate. **SF**

by **DR GILES YEO**

Giles is a geneticist at the University of Cambridge, whose research focuses on food intake, genetics and obesity. He is a presenter on Trust Me, I’m A Doctor.

POWERING BRITAIN'S FUTURE

How our evolving energy needs have shaped the largest machine in the UK

The UK's National Grid is a truly enormous infrastructure. We take it for granted, yet it's vital for powering our everyday lives. The rotation of a wind turbine in the North Sea can feed a light bulb in Bristol – electricity at the flick of a switch. In practice, the grid is much more complicated than this. It's a live energy transmission network, orchestrating the see-sawing supply and demand required at peak and off-peak times, balancing how much power the country can produce with how much it needs. But this hasn't always been the case.

In the early 1900s, electricity was supplied by a mix of private companies and municipal councils, but it was extortionately expensive. Post-WWI Britain needed cheaper, more reliable energy. So the most efficient power stations were connected up in seven areas around the country. Then, one evening in 1937, the control rooms tried combining the seven grids. It worked – and the National Grid was born.

By the start of WWII, two thirds of homes were connected to the grid. Post war, domestic electricity demand sky-rocketed – gadgets like irons and immersion heaters sucked up huge amounts of energy – and manufacturing on electrically driven production lines accounted for almost 40 per cent of GDP in post-WWII Britain.

The electricity industry was nationalised in 1947, but was privatised years later in 1990 when the National Grid became a company with shares owned by 12 regional electrical companies, and the seven control centres were replaced by one base. Over the years, the grid has upgraded into a 'super-grid', distributing electrical power generated in England, Scotland and Wales, and transferring energy between Great Britain, Ireland, France and the Netherlands.

"The Grid now faces its next big challenges"

Power junkies

So far, the grid has kept pace with our energy needs – just. The reality is that we are power junkies. Little in today's world doesn't rely on being plugged in. From smart phones to laptops, ovens to air con, much of what we use for work, rest and play requires electricity. And that thirst for power is about to ramp up.

The grid now faces its next big challenges: the electrification of our vehicles and achieving net zero carbon by 2050.

As new diesel and petrol cars will no longer be sold in the UK from 2030, it is predicted that 35 million electric vehicles (EVs) will be on our roads by 2050. Fantastic news for cutting carbon emissions, especially as the UK still has the capacity to generate enough energy. Improved energy efficiency means peak demand has fallen by about 16 per cent in the last two decades. Even if we all switched to EVs overnight, demand would only increase by roughly 10 per cent. However, peak demand between 6-8pm is exactly when most commuters will return from work and want to plug in their EV. Added to that challenge is the government's EV Energy Taskforce recommendation that all future car chargers be 'smart by design' and only charge outside those peak hours.

Another challenge is that the UK government has signed up to being 'net zero' by 2050, meaning as a country we don't emit more CO_2 than our natural landscapes can absorb. While the last two years were the greenest on record for Britain's electricity system, shifting from fossil fuels to renewables means going from a steady supply of energy to a fluctuating one. Throwing more coal on the fire can

be done at any time, but the wind doesn't always blow and the Sun won't always shine at peak times.

Future solutions

Building large energy storage plants would help to cope with fluctuations in electricity generation from renewables. Currently, lithium-ion batteries (like the ones in your smartphone or EV) can store energy and then release it when needed. The government reckons that technologies like battery storage systems could save up to £40 million by 2050.

Energy storage units are also moving into the home. Devices like the Tesla Powerwall store energy from the grid when there is excess supply and sell it back when there is excess demand. And, if there is ever a power cut, these units work a bit like noise-free generators that don't use fuel.

EVs can also give back to the grid using 'vehicle-to-grid technology' or 'V2G'. Instead of the EV sitting idly on the street or drive, energy stored in its battery feeds into the grid, helping to boost energy supplies at peak times – and earning you a bit of extra cash.

For a smaller scale investment, a smart meter is a good alternative, as in the future it could enable you to make money off any surplus energy you generate. When demand rises, the smart meter could help to sell any surplus energy back to the grid thanks to smart off-peak tariffs. The smart meter's in-home display might also soon let you know when electricity prices are cheaper, signalling the best time of day to run energy-hungry devices like washing machines.

Why get a smart meter?

Some 50% of smart meter owners think their gas and electricity use has reduced since they had a smart meter installed

The average UK household spends an estimated £35 per year leaving electronic devices on standby

If every UK household took action on energy efficiency now, we could save up to 54 million tonnes of carbon dioxide

smart energy GB
Join the energy revolution

Join the **energy revolution** and contact your energy supplier to **request a smart meter.** For more information, visit **smartenergygb.org**

A flexible heart-rate monitor p42

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

Pew pew pew! The cannon blasts high-powered microwaves that overwhelm the drones' electronics

MORE WAYS TO DOWN A DRONE

DRONEGUN MKIII

This handheld, pistol-shaped device fires radio frequency waves to jam the signal between a drone and its operator. With a range of 500m, the gun, developed by DroneShield in Australia, is one of the most portable anti-drone technologies out there.

TRAINED EAGLES

In the wild, birds of prey are known to attack drones that they presumably mistake for food or competition. Now, Dutch police are signing up feathered crimefighters by training eagles to attack drones that stray too close to airports or high-security events.

DRONECATCHER

Designed to guard airports and prisons as well as military and government buildings, this patrol drone intercepts targets mid-air and hovers nearby. It then fires a large net to trap incoming drones and bring them to the ground.

DRONES

Meet the drone slayer

The cannon fires microwaves to take down swarms of attack UAVs

The growing use of drones in combat has been described as the most concerning tactical development since improvised explosive devices (IEDs) became prevalent in Iraq. Small and inexpensive unmanned aerial vehicles (UAVs) are already used for surveillance, disruption of airspace and dropping small explosives, but in the near future swarms of robot vehicles could become even more dangerous – both on the battlefield and around civilian spaces like airports or sports grounds.

To address the issue, military researchers and arms manufacturers are developing directed energy weapons with the power to disable drones using lasers, particle beams, radio frequency waves and more. One of the latest is called Leonidas, created by US start-up Epirus. It uses high-powered microwaves (HPM) to overwhelm drones' onboard electronics.

"OPERATORS SAFELY DIRECT THE HPM BEAM ON TARGET TO DISABLE ENEMY THREATS AND NOTHING ELSE"

The system uses gallium nitride semiconductors to produce extreme levels of power density while firing the HPM. Operators can narrow the beam to target individual drones, or take down multiple threats across a wider field. Epirus staged a demonstration event for government officials earlier this year and the device disabled all 66 drones sent to swarm around it.

"Our state-of-the-art digital beam-forming capabilities allows operators to safely direct the HPM beam on target to disable enemy threats and nothing else," says CEO of Epirus Leigh Madden. "These capabilities were on full display at a recent customer event where Leonidas executed multiple precision strikes, disabling an enemy target and leaving a blue force drone untouched."

Unlike some directed energy weapons, Leonidas is small enough to mount on a truck or boat, and its rapid-fire capabilities make it practical on kinetic battlefields. Epirus is also in the late stages of development for even more compact and portable systems, and the technology could eventually lead to some kind of microwave gun.

Anti-drone weapons may also be required beyond the battlefield. As UAVs become cheaper and more prevalent, so too does their potential for harm in civilian spaces. In December 2018, London's Gatwick Airport closed for two days after mysterious (and never-found) drones were reported in the skies around the runways. Fearing a collision could take down a passenger aircraft, the military was deployed and more than 1,000 flights were cancelled.

Other identified threats include recreational drones flying too close to rescue helicopters, attacks in civilian spaces, reconnaissance of nuclear sites, invasion of privacy and even as a distraction to aid criminals.

Madden says that while Epirus is currently focused on work with the US Department of Defense, it is also in discussions to "bring new products to market and support additional use cases across industries."

At an event, the Leonidas cannon successfully disabled 66 drones sent to swarm around it

DELFT DYNAMICS BV, GETTY IMAGES

INTERVIEW

Introducing your digital twin...

↑ This is an illustration of the idea, nothing to do with the actual device, as the company are keeping their final design a bit of a secret

Imagine a *Star Trek*-style body scanner that examines your body in such depth that it can produce a 3D computerised model to track your health. Jeff Kaditz didn't just imagine it, he built one. He's the CEO of QBio, a US start-up that wants to facilitate a data-led, personalised approach to medicine. The firm's scanner measures hundreds of biomarkers in a person's body and tracks them over time in a so-called digital twin – a sort of databank-cum-avatar of your body. Here, he tells us what the physical exam of the future looks like and how it will revolutionise healthcare.

WHAT IS A DIGITAL TWIN?

It's a three-dimensional digital model of something. It isn't new, actually. In manufacturing, having a digital twin of, say, an aeroplane engine lets you tweak the design and see how it affects the model. The human body is different. It's more that we're tracking what's changing in a digital twin across all these different biomarkers of your body, and identifying the progression of disease much earlier. So it's more of a diagnostic.

HOW DOES THE SCANNER WORK?

The core physics that it uses is magnetic resonance, plus a lot of other sensors. The most important thing for us is that we could do these entire full-body scans in 15 minutes or less.

HOW HAS THE PANDEMIC AFFECTED YOUR WORK?

The coronavirus has actually helped to tell our story. The way we envision the future of healthcare is similar to the way we've done triage for COVID. You have these low-cost, drive-through sites where you don't really need highly skilled labour to operate them. In 20 minutes, I get my nose swabbed, I go home and I get a text message if I have to go in.

We think the same thing should be done for the entire body. Imagine you have low-cost sites where, in 20 minutes, everything can be measured about your body, once a year. And if there's an issue, you get a notification on your phone.

WHAT DOES THE SCANNER MEASURE?

The scanner looks at structural change, so it's really measuring things on the size of a thousandth of a metre and then looking for changes there. We can measure properties and structures in your body and correlate that with genetic risks and chemical risks taken from more traditional tests.

HOW MANY BIOMARKERS DOES THE TEST MEASURE?

It's going to be in the many hundreds. The amount of fat in your liver, the amount of visceral fat in your body, fat infiltration of muscles as you get older. There are certain volumes of the structures inside your brain that we know are related to dementia or degenerative diseases. The list goes on and on. And the rate at which these things change can tell you a lot.

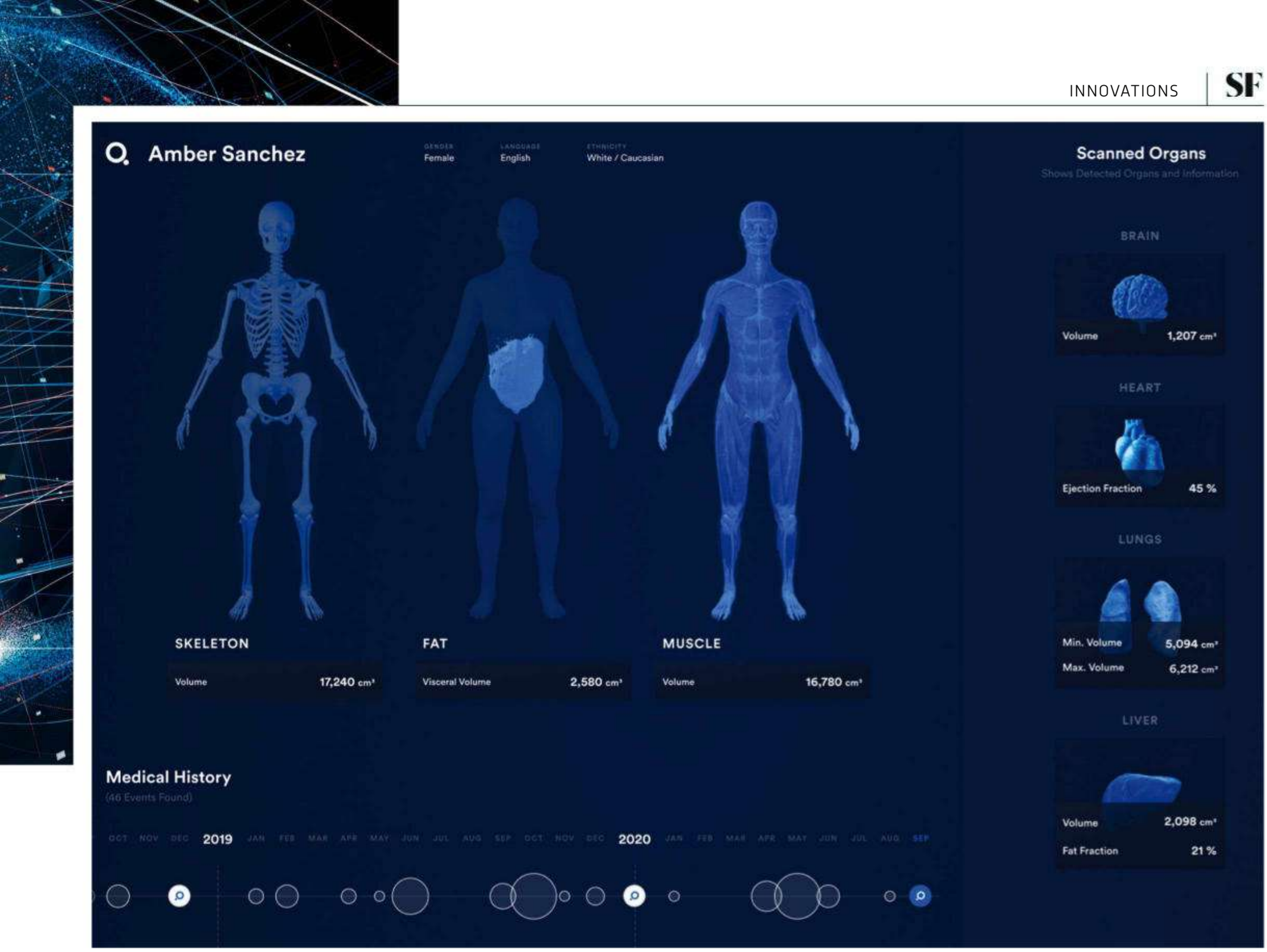
WHAT'S THE ADVANTAGE OF SEEING CHANGES IN THE BODY OVER TIME?

Right now the way diagnostics are done is based on single variables measured at a single point in time. And they don't work. The analogy I like to use is [the app] Shazam: you play a song and it identifies it quickly. If you played a single note and sent it to Shazam that wouldn't work because lots of songs have the same note. You need to see the sequence of notes to see what makes the song unique.

WHAT ARE THE ADVANTAGES BEYOND DIAGNOSTICS?

One big beef that I have with the healthcare system is that we tend to store the output of our analysis, such as a doctor's diagnosis, but not the data that went into the decision. So we can't learn from mistakes. To me, the real value for this platform is in triage.

↓ CEO of QBio Jeff Kaditz



SO WORKING OUT WHO ACTUALLY NEEDS HEALTHCARE?

Yeah. A doctor's time is really the most precious resource we have in healthcare because the population is growing faster than we create doctors. Doctors are getting burned out. What we need is the ability, without any skilled labour, to stratify risk in a population. The opportunity here is if we can gather enough information, we can say, "Here are the 200 patients you need to see as soon as possible. The rest of them you probably don't need to see this year." Right now, healthcare is first-come, first-served, which is really bad.

HOW MUCH DID YOUR OWN EXPERIENCE WITH THE HEALTHCARE SYSTEM HELP YOU TO SHAPE THIS PLATFORM?

I had a situation where I was 27, an active triathlete, and I was told I was fine. Then three months later I was told if I don't get a hip replacement in the next week then they may have to amputate my leg. But the specific experience was less important than the generalisation: we all know people who have had terrible experiences with the healthcare system. Someone has these weird symptoms and they don't know what's wrong. They get bounced around specialists and every time they see a new doctor, they measure the same things they've already measured. By the time they figure out what's actually wrong, it's a year later and it's now not treatable.

↑ The QBio scanner would take measurements of your body every year, and then flag up any changes that could be a cause for concern

ARE YOU CONCERNED THAT AS WE GET MORE AND MORE DATA ABOUT OUR BODIES IT WILL LEAD TO GREATER HEALTH ANXIETY FOR SOME PEOPLE?

I think that has to be a consideration. But on the other hand, not looking at the data is almost as valuable as capturing and looking at it. I eat healthily and exercise, but I'm not a health nut or biohacker. I want to live my life. I'm fine having all the data recorded and stored somewhere, because it's an insurance policy. I'm preparing for the time when doctors need this information to figure out what's wrong as quickly as possible.

DO YOU HAVE A ROAD MAP FOR HOW THIS TECHNOLOGY CHANGES THE WORLD?

We have more than a 10-year road map in terms of where this can go, but I won't be satisfied until we've effectively replicated med bay in *Star Trek* where I can walk into a room, talk to a virtual personality, they can tell me if there are any problems and potentially fix them on the spot.

Ideas we like...

→

....a robotic camera operator

This motorised phone stand will pair with your iPhone 12's face-tracking to follow you around a room while you strut your stuff on TikTok (no? Us neither), film a YouTube video or make a Zoom call. It capitalises on the iPhone 12's MagSafe tech, so you can just magnetically snap the phone into place and get going.

Belkin magnetic phone mount with face-tracking
£44.99, belkin.com

↑

...an interchangeable heart-rate monitor

This fitness tracker is ready for anything, even if you're not. The MZ-Switch measures your heart rate to understand how much effort you're putting into your exercise. What makes it unique is that this tracker can slot into different straps to read your heart rate from your wrist, arm or chest. It's waterproof too, so there are few activities it won't track. In my case, that means it'll be able to tell me precisely how much of a slob I am.

MyZone MZ-Switch
£139, myzone.org

↓

...an all-in-one streaming headphone amp

If you want to put on a pair of headphones, dissolve into an armchair and forget the world for a couple of hours, this Naim streaming audio system might be the best way to do it. This new edition of the Uniti essentially squeezes all the hi-fi equipment you might need to produce high-fidelity audio into one small box (headphones not included). Inside there's a digital-to-analogue (DAC) converter and a headphone amplifier, as well as a whole bunch of tech designed to optimise your music library for playback on your cans. It's a self-contained system with hi-res streaming services like Qobuz and Tidal installed, alongside the likes of Spotify and Apple Music. You can also connect it to your smartphone or laptop, with or without wires.

Naim Uniti Atom Headphone Edition
£2,399, naimaudio.com

←
...an affordable, easy-to-use instant camera

Generally speaking, we tend to look forwards here at *Science Focus*, but this retro, instant camera from Fujifilm is too cute to ignore. There are two modes and two buttons: one for selfies and one for normal shooting. A button beneath the lens pops the lens out so it can get up close and personal for selfies. There's even a teeny tiny mirror embedded into the body so you can get a sense of what your framing in your shot. Then you just click the shutter button and wait 90 seconds for the AA-battery-powered printer to process your photo.

Fujifilm Instax Mini 40
£89, instax.com

↑
...a modern hearing aid for a tech-savvy generation

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INSTALLING A NEW AGE OF HUMANITY

WORDS: HAYLEY BENNETT

PHOTOGRAPHY: DAVID VINTINER

FROM REALITY-ENHANCING IMPLANTS TO BRAIN-CONTROLLED EXOSKELETONS, BREAKTHROUGHS IN BIO-TECH HAVE FUELLED A NEW FUSION OF MACHINERY AND ORGANIC MATTER. HERE WE SPEAK TO THE CYBORGS WHO ARE HELPING HUMANITY TRANSCEND ITS BIOLOGICAL LIMITS, ONE DEVICE AT A TIME

'Eyeborg' Rob Spence is a filmmaker who lost an eye following a gun accident. He created a wireless video camera eye as a replacement, which is hooked up to a remote receiver. He has several different versions, including this Terminator-style one.

Humans are integrating with technology. Not in the future – now. With the emergence of custom prosthetics that make us stronger and faster, neural implants that change how our brains work, and new senses and abilities that you've never dreamed of having, it's time to start imagining what a better version of you might look like.

Some call it transhumanism. It's not a philosophy cybernetics expert Kevin Warwick associates himself with, but he can't deny he's a cyborg... or was. Warwick had a 2.5cm-long radio frequency identification (RFID) chip implanted in his arm in 1998. Back then it was considered risky, even reckless. He went ahead anyway, creating a media circus as he demonstrated how the chip made him remotely traceable to a computer and allowed him to open the automated security doors at his University of Sheffield lab without touching them.

Four years later, despite warnings from the surgeon, he had neural interfaces implanted that allowed him to control a robotic arm on another continent and communicate, nervous system to nervous system, with his wife, Irena, via electrodes in her arm. "That was the most profound thing I did," he says, recalling how he first felt the pulses of her transmitted signals in his finger.

Warwick eventually had his implants removed, but he remains, for some, the original cyborg. Others look upon such tampering with the human body simply as a progression of what's been happening for thousands of years. For Liviu Babitz, co-founder of London-based company, CyborgNest, which makes sensory enhancement devices, we've been integrating with technology since we started aiming arrows at bears. "Isn't an arrow an extension of your hand?" he muses. According to Babitz, "we're all cyborgs at this stage," though he admits the technological enhancements are becoming "more intimate" now.

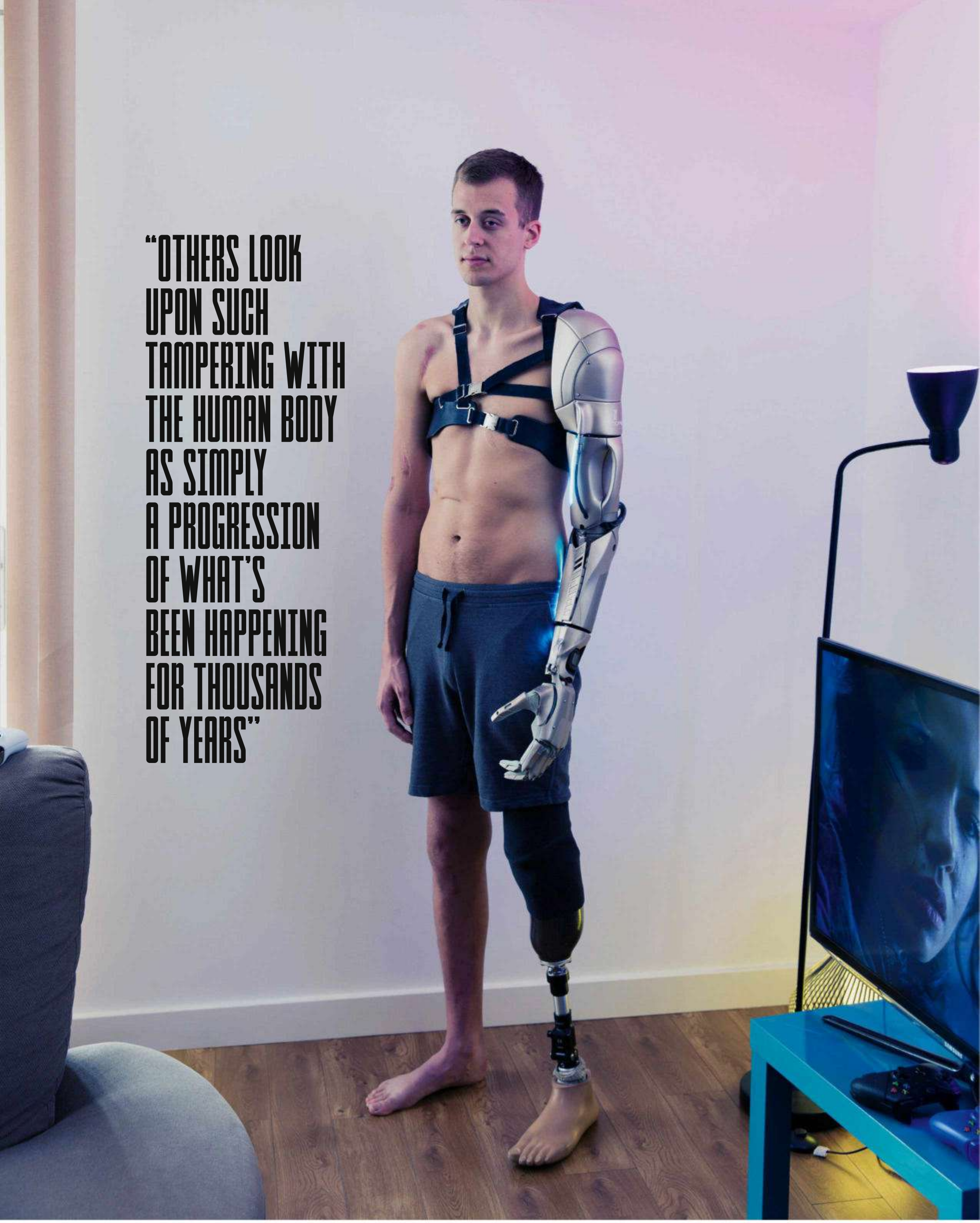
Warwick's later implants were certainly too intimate for most people, but biohackers are now getting similar RFID devices and magnets implanted. Some even get implants in their ears that function like internal headphones for playing music. Meanwhile, in the medical world, modifications such as hip replacements and prostheses offer benefits that outweigh the risks. These are intended as treatments rather than extensions of our human selves, but they cross a line when they offer enhanced or entirely new abilities, like James Young's carbon-fibre, gadget arm (see image, right).

ABOVE Two of Rob Spence's bionic eyes, with a natural-looking one on the right.

RIGHT James Young had an accident that left him a double amputee, so he turned to bionics to redesign his body. With funding from video game giant Konami, prosthetic sculptor Sophie De Oliveira Barata created him a bionic arm that's fitted with a 3D-printed hand that's controlled via sensors that detect muscle movements in James's back. The arm also boasts a USB charger, Twitter connectivity, a torch, a heart monitor and a small drone.

BEYOND SENSES

If a permanent implant is a step too far for you, then Babitz's company makes 'wearables' such as the NorthSense, a device worn close to the skin that vibrates to tell you where magnetic north is. It's not just a compass, he says – it's a whole new sense. Just like regular biological senses, the NorthSense is permanently 'on', allowing you to perceive how you're oriented in the world. "Every time you face magnetic north, you know that's happening," he says.



“OTHERS LOOK UPON SUCH TAMPERING WITH THE HUMAN BODY AS SIMPLY A PROGRESSION OF WHAT’S BEEN HAPPENING FOR THOUSANDS OF YEARS”

and ultraviolet. "Now he's got an appreciation of the outside world that humans don't have," says Warwick.

The implant also has internet connectivity. For his next project, Harbisson is planning to sell 'access to his head' via non-fungible tokens, units of data that promise to be the next big thing in digital art. "You'll be able to send colours to my head, so anyone that buys me will have permission to alter my perception of reality as well as receive the colours that I'm sensing right now," he says.

MIND HACKERS

While such projects demonstrate the potential to influence the brain through other bodily modifications, there's a more direct way to get mind-altering effects: place the implant directly into the grey matter. That's the goal of Elon Musk's venture, Neuralink, which aims to create a "high-bandwidth brain interface", a wireless implant that could see us accessing the internet with our minds.

Researchers at Neuralink recently announced that they'd succeeded in getting a monkey to play the computer game *Pong* with its mind by accessing its motor cortex, the region of the brain that controls movement. Sounds impressive, right? Not to Warwick, who'll be more excited if they can get two monkey brains, or two human brains, to communicate, like when he and his wife connected their nervous systems. "That's the experiment I would like to see," he says. "[Musk] is using motor neural signals exactly the same that we did, but it would be nice if he got on to other signals."

In the short-term, Neuralink plans to make devices to treat paralysed people and here Warwick is thinking along the same lines – he reckons that we'll be able to "patch over breaks" in the spinal cord to treat paralysis within the next decade.

Meanwhile, there is an electrode device called a BrainGate (originally built by US company ➲

"THE ANTENNA ALLOWS HIM TO 'HEAR' IN COLOUR. FREQUENCIES ARE CONVERTED TO VIBRATIONS VIA A MICROCHIP IN THE BACK OF HIS HEAD AND CONDUCTED THROUGH HIS SKULL"

➲ "So that starts to embed into your life like your smells and colours." Babitz says it adds new information to memories, for example, about where you were at a particular moment.

While the NorthSense can be worn discreetly under clothes, the sensory enhancement device that Barcelona-based cyborg artist Neil Harbisson uses is more conspicuous. Born with greyscale vision, Harbisson's antenna (originally an attachment, now an implant) allows him to 'hear' in colour. Colour frequencies are converted to vibrations via a microchip in the back of his head and conducted through his skull. Far from being about fixing anything, he says, the antenna was conceived as an art project. "When I was studying experimental art they talked to us about pushing the boundaries, so it came as an artistic challenge for me," he says, adding that it has since become a "life project".

Warwick considers Harbisson's implant in a 2020 paper about superhuman enhancements, published in the journal *Philosophies*. He regards Harbisson as "on the cusp" of superhuman, particularly following upgrades that allow him to sense beyond the visible spectrum into infrared

LEFT Kevin Warwick, considered by many to be the world's first cyborg, had a neural system implanted that allowed him to control a robotic hand via his brain signals from anywhere in the world.

RIGHT Rin Raeuber has had magnets implanted under skin of their hands (one under the fingertip of the right hand, one on the edge of the left hand). They can pick up bottle caps, screws and spoons, and detect magnetic fields.

BELOW RIGHT NeuroRex is a brain-controlled exoskeleton that helps improve independence and quality of life for disabled people.

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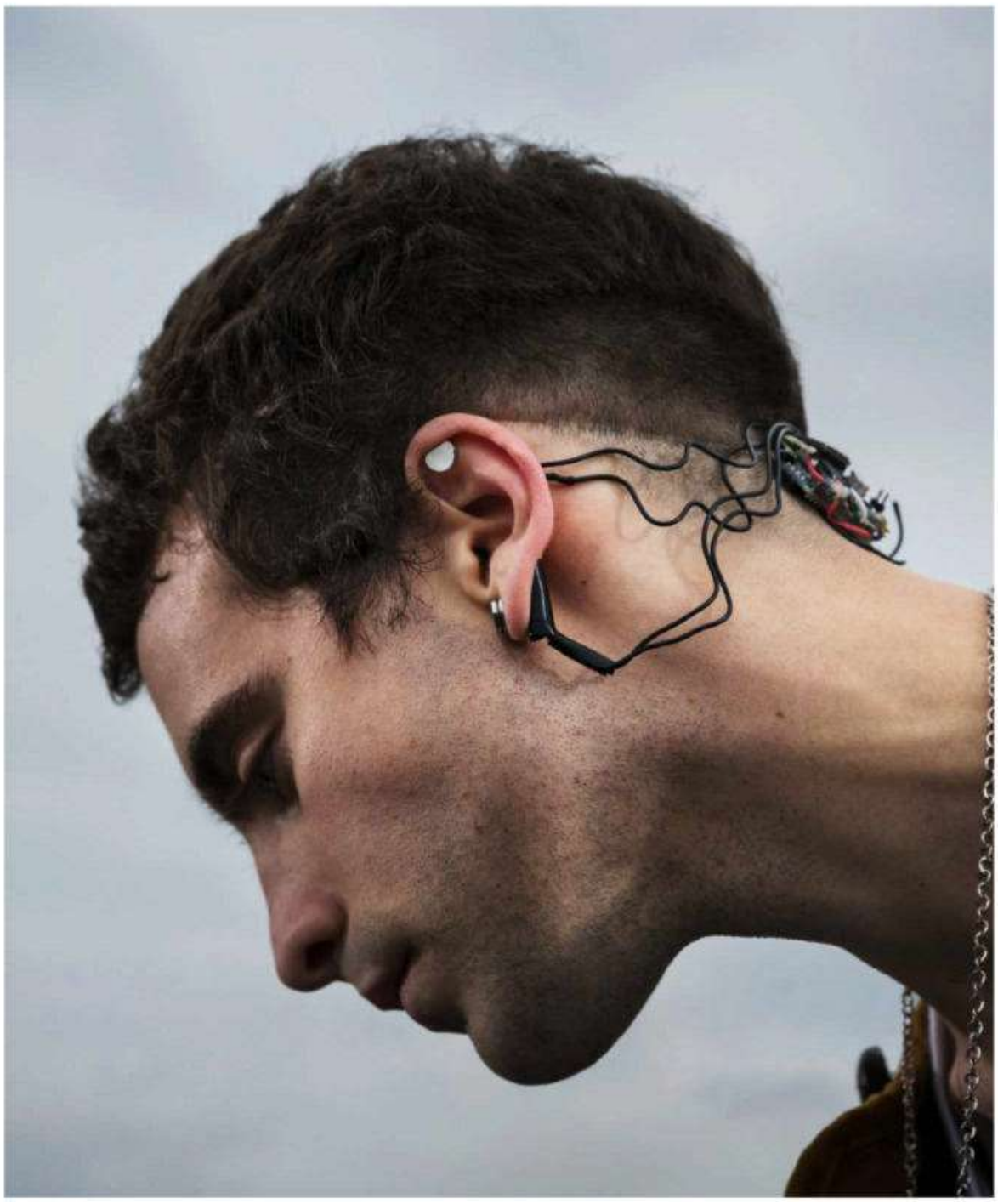
"BRAIN-MACHINE AND NEURAL INTERFACES ARE ALREADY AVAILABLE FOR CERTAIN CONDITIONS, BRINGING MAJOR LIFE IMPROVEMENTS"



LEFT Neil Harbisson, who was born colour blind, has an antenna implanted into his head that lets him 'hear' in colour.

BELOW Cyborg artist Manel Muñoz has biometric ears that allow him to detect changes in atmospheric pressure so he can predict the weather.

Cyberkinetics) that has been implanted into the brains of paralysed people, allowing them to type and search the internet with their minds. Until recently, they had to be 'wired in' at all times through a port in their skulls. In 2021, however, US researchers announced they'd upgraded devices previously installed in two tetraplegic men to wireless transmitters, allowing cable-free browsing.

BrainGate has so far benefitted only a handful of patients, but brain-machine and neural interfaces are already available for certain conditions, bringing major life improvements with them. Warwick, for example, works on deep-brain stimulators that quell tremors caused by Parkinson's disease, while cochlear implants that stimulate the auditory nerve give people with hearing loss the ability to hear. Being medical implants, they don't offer superpowers, but they could pave the way towards more widespread enhancements.

HEAD OVER HEART

According to Dr Timothy Constandinou, head of the Next Generation Neural Interfaces Lab at Imperial College London, there could one day be neural interfaces for everything from asthma to sleep problems. But as governments race to put safeguards in place, there's the issue of major brain surgery to consider. One way to reduce the risk is to make the implants smaller and Constandinou is working on a brain interface the size of a pinhead.

"It's 1,000 times smaller than your typical implant device, so the idea is to make these devices wireless and implantable using minimally invasive surgery," he says. Implants could be sprinkled around the brain like seeds during keyhole surgery or, eventually, injected.

Without a medical complaint to cure, though, would you risk it? Should you be able to? Even Warwick, among the most daring of self-experimenters, draws the line at brain surgery. Harbisson, meanwhile, says there should be no limits on how you can change your own body, if you want to. For him, the cyborg revolution is progressing too slowly. "I'm surprised that this is still not mainstream," he laughs, indicating the antenna on his head.

Asked whether CyborgNest will be expanding into implants, Babitz replies: "when they become as comfortable as taking a paracetamol". For now, he thinks there's plenty of benefit to be had from enhancing the brain via wearable technologies, which can be mind-extending, whether they're physically embedded or not.

So, when brain implants become pill-poppingly simple, how should we use them? Warwick has thought about this: he is dreaming of a future where we can link our brains to artificial intelligence systems, a fusion he thinks would lead to breakthroughs in areas such as space travel. "Suddenly," he says, "*Star Trek* becomes possible." **SF**

by **HAYLEY BENNETT**

Hayley is a freelance science writer and editor, based in Bristol.

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Check out Michael's new podcast *Just One Thing*, available on BBC Sounds
bit.ly/just_one_thing

ALAMY

JUST ONE THING...

Being healthy and fit demands hard work, dedication and time. Or does it? Dr Michael Mosley shares his favourite shortcuts to staying healthy as we get older. No sweat bands necessary...

WORDS: IAN TAYLOR

There is a slightly condescending phrase that perky fitness trainers are fond of saying to anyone lacking the motivation to train: "If you don't have 20 minutes a day to invest in your health, you're lying to yourself!"

They're not wrong, of course, but who says that those 20 minutes have to be spent hyperventilating on a treadmill? Not Michael Mosley, for one. The broadcaster, author and health hacker has a new podcast series called *Just One Thing*. Available to download from BBC Sounds, its aim is to reveal surprisingly simple things you can do to boost your health and wellbeing. Each episode covers a short, sharp intervention – from cold showers to gorging on sauerkraut – that could literally change your life.

"I wanted to look at things that people could easily fit into their lives, which they might not be doing at the moment and where there was some real science behind it," Mosley explains. "I do it, and another person – a member of the public – does it too, and I also interview a leading expert about how strong the science is."

Mosley has long been an enthusiastic guinea pig for the science he reports on. He is widely credited with popularising intermittent fasting, and even used a low-calorie diet to reverse his own type 2 diabetes. He's also made programmes on sleep, exercise, meat-eating and e-cigarettes, plus many other topics, on BBC Two's *Trust Me, I'm A Doctor*. In short, he's made a career out of living longer. Good work if you can get it.

"Of the 10 things we cover in this series, I still regularly do eight of them," he reveals. He eats fermented foods such as kimchi, practises gratefulness, takes morning walks in green space and, at the age of 64, can probably do more press-ups than you can.

"One of the most surprising things was the cold shower," he says, of the increasingly popular way to boost your immune system. "I never thought I would get into cold showers but I'm actually enjoying them now. It's taken a while – several weeks – but I actually get in and frolic around. I sing a bit. And it's no longer a pain. I've got into it and it makes me feel brighter and alert."

Conversely, Mosley didn't enjoy taking hot baths in the evening, which was another intervention that he explored on *Just One Thing*, which is linked with improving insomnia. "I just felt I didn't want a hot bath in the evening and a cold shower in the morning," he says. "I didn't really find it did much for my sleep anyway."

The other one he hasn't continued with is learning a new skill – a surprise, considering he's known for having a crack at things. "I was picking up drawing and to be honest, I'm terrible at drawing. What I'd like to do is pick up dancing instead. I'm waiting for things to open up [after lockdown fully ends]: Zumba, I think."

Over the page, we delve into the science behind the 10 habits and behaviours Mosley covers in the series. Just don't pretend you haven't got time to read about them.

ESCAPE TO *GREEN SPACE*

One of the lessons that coronavirus lockdowns taught us was the value of green space for general wellbeing. But while that was news to some, researchers have been cataloguing the benefits of time spent in nature for decades. One famous study, for example, looked at people recovering from operations in a hospital. Those in a ward with a view of green space recovered sooner and required fewer painkillers than those who didn't have a view.

In Japan, the concept of 'shinrin yoku' or forest bathing is both popular and reasonably well-studied. It describes the process of spending time among trees, staying calm and still, as you observe the sights and sounds of nature. Researchers have found this can lower both your blood pressure and cortisol levels, while increasing the levels of your body's natural killer cells – the frontline soldiers for your immune system that can control infections and even tumours.

"The NHS in Scotland seems to be sufficiently convinced that GPs can prescribe time in nature now," Mosley says. "Plus, it's just enjoyable. I have a wood near me and it's lovely to be there."

18+

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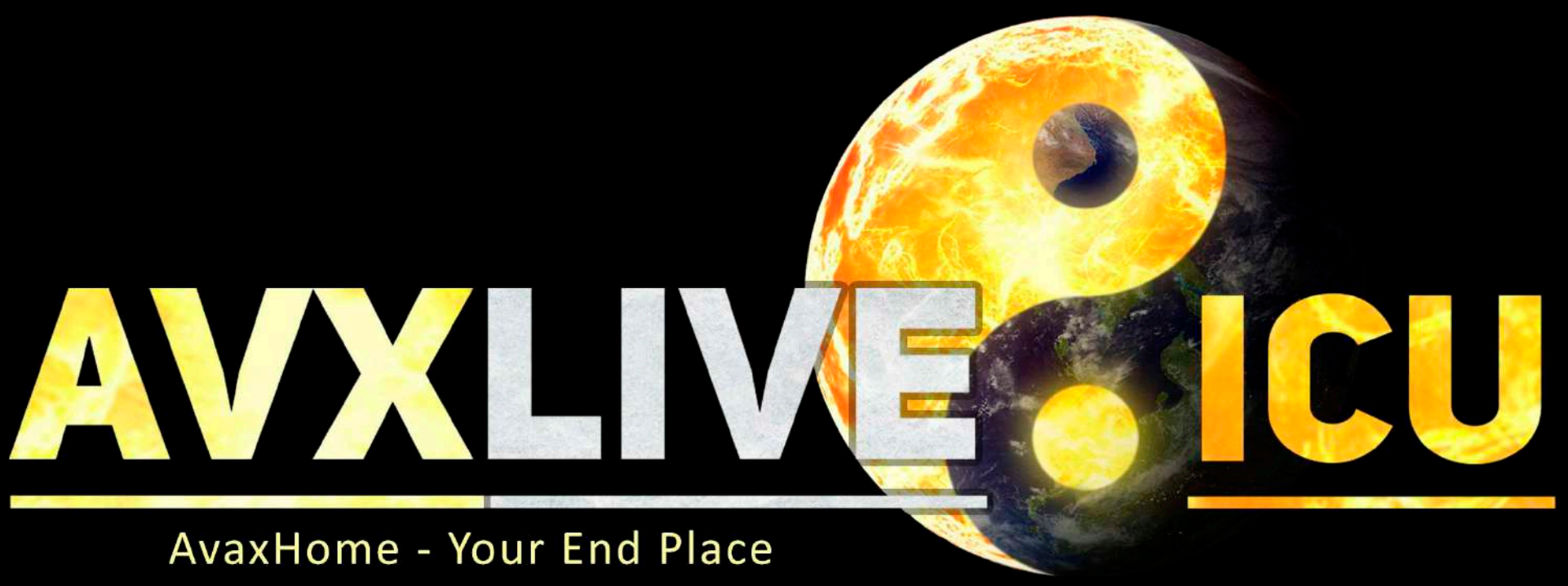

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ALAMY X2

EAT SOME *BACTERIA*

As you're probably aware, your body is home to a teeming mass of other species, including bacteria, viruses and fungi, which are collectively known as the microbiome. Evidence is mounting that your personal microbiome – as individual to you as a fingerprint – can have major implications on your health, so feeding it the right stuff is essential. Fermented foods are top of the list.

These foods, which include sauerkraut, kimchi and kefir, are produced by the controlled growth of beneficial microorganisms, which break down carbohydrates and turn them into other chemicals. The bacteria add healthful diversity to your microbiome. Clinical studies are a little sparse, but it's suggested that diets rich in fermented foods have widespread benefits, including lower risk of diabetes and metabolic syndrome, improved weight management and better digestive health.

There's also intriguing new evidence that the microbiome could also impact your brain. Early research at APC Microbiome Ireland suggests that getting the right bacteria in your diet could improve cognition, mental health and lead to healthier ageing. Mosley is a convert: "I make my own sauerkraut and kimchi and we also make kombucha," he says. Get pickling.

TAKE AN *EARLY MORNING WALK*

Banking 10,000 steps a day is one of the magic numbers that self-tracking health nerds all aspire to, but how and when you get those steps can have a big impact on just how beneficial the exercise is. A purposeful stomp soon after you wake can improve your sleep, speed up your metabolism and boost your mood and cognitive function. "It's about the time you go for your walk and the briskness of your pace," Mosley says. "The advantage of an early-morning walk is that you get out there and get exposed to light, which will reset your internal clock, and we know that light is a powerful suppressor of melatonin and gets you going."

As well as shutting down melatonin, which is a hormone that makes you feel tired, exposure to sunlight also boosts serotonin, improving your mood. The earlier you do it, the better the effects seem to be. In research from Tokyo University of Science, insomnia sufferers found it easier to drop off and woke up less frequently after engaging with early-morning exercise.

"The briskness seems to be important, too," Mosley says. "You get more benefit if you're doing more than 100 steps a minute than if you're doing under. If you can aim for 120 there seems to be something optimal about that." A study involving 50,000 people by Ulster University found that getting a move on when you walk can boost its effectiveness by 20-50 per cent, with a significant reduction in your risk of cardiovascular disease. Up and at them, and all that.

LEARN A *NEW SKILL*

Always be learning. Yes, that sounds like the kind of thing your uncle would post on social media but maybe, just maybe, your uncle is a neuroscientist. Learning new skills is a well-established way of boosting your brain power and slowing mental decline as we age.

The reason is that when we learn something new – it could be a sport, a language, different skills at work – our brains make new neural pathways and patterns. The density of our brain's white matter increases, and so does our processing speed. Over a lifetime, these cognitive jolts can help to stave off neurodegenerative disease.

Researchers at the Mayo Clinic in the US studied a group of people who carried the APOE4 genetic risk factor for Alzheimer's disease. Older people with the APOE4 genotype tend to have lower cognitive function, but this study found that APOE4 carriers with a high level of lifelong learning delayed their cognitive impairment by an average of nine years.

The trick is, you can't just fall back on the stuff you know you're good at. You have to challenge yourself (and your brain) to make those connections by trying new things. On the plus side, there's a good chance that it will make you feel great, too. London Economics, a policy and economics consultancy, carried out a survey for the government's Department for Business, Innovation & Skills and found that 80 per cent of learners had improved self confidence or self-esteem as a result of their learning.

STAND ON *ONE LEG*

One of the rotten things about getting older is we sometimes lose the ability to make choices about the movements we make. We could get stiffer or slower, develop arthritis or inner-ear issues. These things can lead to issues with our sense of balance, and when that goes, it can lead to a negative spiral of health outcomes. You exercise less because you find it harder to balance, which may lead to weight gain, causing you to exercise even less. Insulin sensitivity, blood pressure and heart issues can – and often do – follow.

It's why researchers like Prof Dawn Skelton at Glasgow Caledonian University think we should all be doing specific balance training over the age of 45 when balance issues can begin to present, if not younger. It gives us a vital foundation for physical fitness, extending the years we spend active and healthy, and boosts our brain power in the process.

"By doing a balancing exercise, you are challenging your brain to constantly practise keeping you upright," Skelton says. "We have to fight the urge to stop doing something when it makes us feel a bit wobbly."

She recommends anything from standing on one leg while the kettle boils to tai chi and racquet sports. Anything that asks you to change direction or control your body in different planes is ideal. Do them often, mix it up and keep your brain guessing. Studies have linked improved balance with better bone health, lower risk of a stroke and lower risk of all-cause mortality over a 15-year period.

ALAMY, GETTY IMAGES

TAKE A *COLD SHOWER*

A cold shower is close to a textbook definition of a rude awakening, but forcing yourself under a jet of icy water will do more than blow away the cobwebs. There's growing evidence that cold water immersion is not only good for your immune system, but could improve mental health and even protect your brain from neurodegenerative conditions like Alzheimer's disease.

"It's reasonably robust science," Mosley says. "There was a decent-sized trial looking at the impact of cold showers in a Dutch population and that did seem to affect the amount of time they took off work with illness. You certainly see changes in cold water immersion in animal studies and some human studies, with an impact on the immune system."

Scientists believe the shock of cold water immersion triggers an inflammatory response that jump-starts your immune system. At Plymouth University, researchers have published a number of studies looking at whether the cold shock also resets your sympathetic nervous system, making your body better able to deal with everyday stresses.

Last year, researchers from Cambridge University also reported interesting findings from a study on cold water swimmers at London's Hampstead Ponds. Regulars at the ponds were found to have higher levels of a protein in their blood that's been shown to slow the onset of dementia and even reverse some of its effects.

Before you go too cavalier with the cold tap, however, it's worth noting that cold water immersion is not for everybody. Talk to your GP first if you have a history of heart disease or asthma, and if you want to try swimming rather than a shower, research ways to do it safely, especially if you're a beginner.

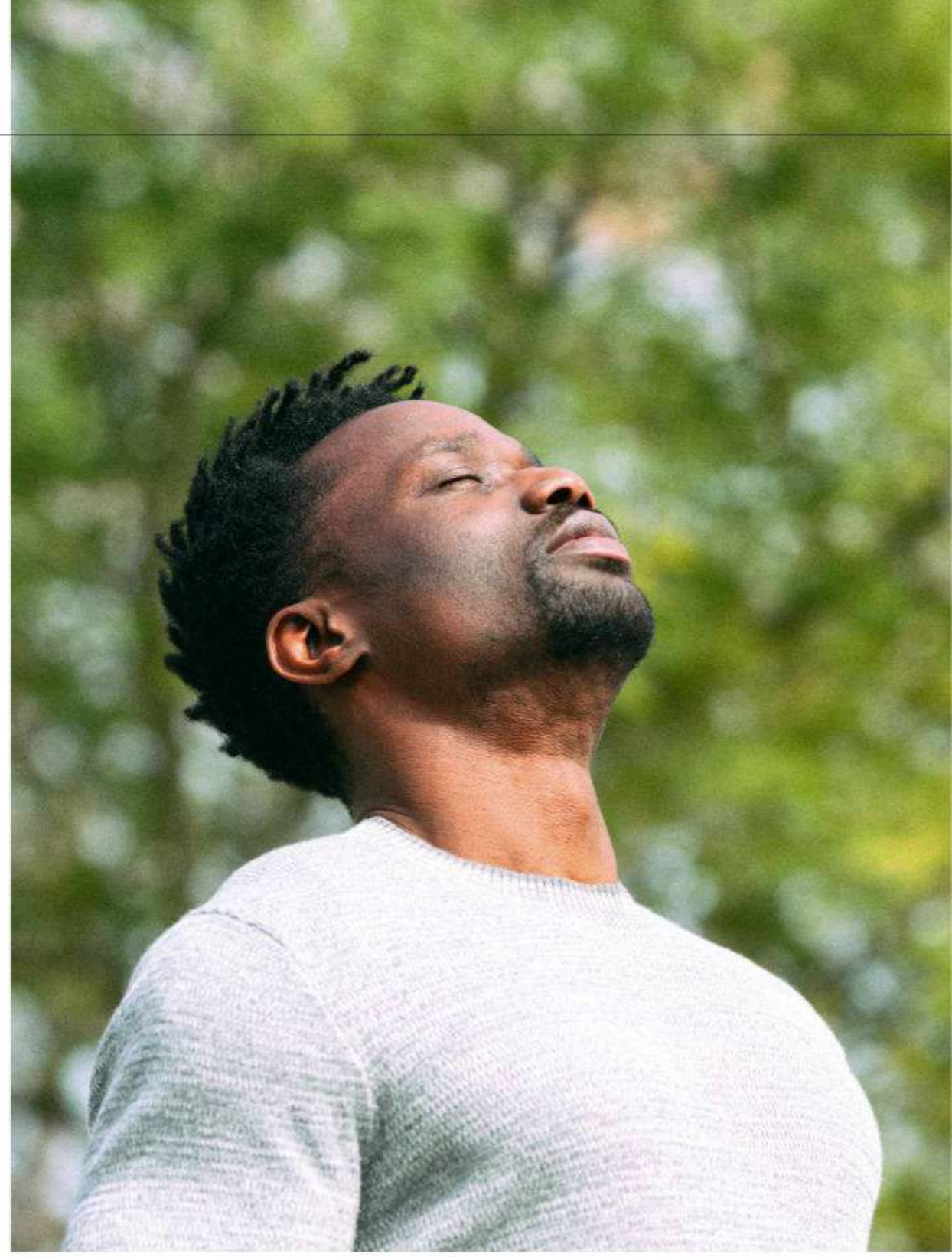
For Mosley, 45 seconds under the cold tap each morning is enough. "With cold water, it seems to be a skin effect," he says. "If you hang around too long, it gets into your tissues and that's not a good thing. But it certainly invigorates."

DO SOME *PRESS-UPS*

Drop and give us 20. Better yet, make it 40. Research at Harvard Medical School found that men who could do 40 press-ups had a 96 per cent lower risk of cardiovascular disease than those who could do 10 or less. Dr Justin Yang, who led the research, says it's less about having big biceps and strong shoulders, and more about what the ability to do so many press-ups tells us about our general strength and aerobic fitness. "The ability to do this many push-ups serves as an indicator of one's risk of a cardiovascular event later on in life," he says.

While Yang says that cardiorespiratory fitness remains the gold standard for judging and indeed improving somebody's heart health, there is emerging evidence that strength can also prolong our lives. "There are suggestions that grip strength, for example, correlates with lower blood pressure," he says. Likewise, a 2018 study in the *Journal Of Gerontology* found that people with low muscle strength are 50 per cent more likely to die early than stronger peers.

If press-ups aren't your thing, try squats instead. Not only do they build muscle, but a study last year by the University of Southern California suggested you could help stave off obesity, heart disease and type 2 diabetes if you squat or kneel instead of sitting down. The study looked at the Hadza tribe, who live in Tanzania. They squat instead of sitting and, despite resting for the same amount of time as we do in Western countries, their incidence of such diseases is much lower.



TAKE A *BREATH*

'Breathing makes you live longer' doesn't sound like a groundbreaking discovery, but how we breathe is a subject of growing fascination for both wellness converts and bona fide biomedical researchers. It seems many of us are doing it wrong.

Scientists are finding that deep, slow, purposeful breathing can improve your heart health, reduce anxiety and enhance your brain power by helping you make better decisions. We've known for years that breathing exercises can reduce symptoms of depression and anxiety, while a 2017 review by scientists at São Paulo University found that it can also lower your blood pressure. In another study, pre-operative breathing exercises were associated with a lower risk of complications after heart bypass surgery.

"It has an impact on your parasympathetic system [rest and digest] and that is opposite to your sympathetic system [fight or flight], so it slows your heart rate down and basically just calms everything down," Mosley says. "There are quite a few different breathing techniques. The one the NHS recommends is 4-2-4, and that's the one I do myself."

Breathe in, counting to four, hold it for two and breathe out for four. It's also known as 4-6: you can simply breathe in for four and breathe out for six. "I do it when I wake up at 3am in the morning, which I often do, and it's very soothing."

HAVE A *HOT BATH*

Lots of people indulge in an occasional bath to unwind, but studies suggest it should be a regular habit. Researchers at Osaka University tracked 30,000 Japanese adults over 29 years, and found that daily hot baths are associated with a 28 per cent reduced risk of heart disease and a 26 per cent reduced risk of stroke. They believe the hot water lowers your blood pressure and improves the heart's ability to pump blood.

Still not convinced to reach for the bubble bath? Separate research found a hot soak can raise your metabolism and help control your blood sugar similarly to 30 minutes of walking. Time your bath 90 minutes before bedtime and you may even get a better night's sleep thrown in for free. A team at the University of Texas at Austin found this can help you fall asleep 10 minutes sooner than you otherwise might. It works by raising your core body temperature to such a height that it has to then fall – and a natural drop in body temperature is one of the triggers your body uses to prepare itself for sleep. *BBC Science Focus* has not been able to verify whether a glass of wine and a trashy novel has any bearing on the bath's effectiveness...

by **IAN TAYLOR**
Ian is a freelance writer and editor.

COUNT *YOUR BLESSINGS*

It's been a difficult 18 months, but finding reasons to be grateful could help our mental health, and more besides. "Research, including my own, has shown that people who have more of a grateful mindset tend to be more resistant to issues with anxiety and depression, even when they're living with a chronic health condition," says Dr Fuschia Sirois, who researches gratitude at the University of Sheffield. She says that people who invest time in being grateful also enjoy better sleep because they have fewer negative thoughts before they go to bed. In one study, an attitude of gratitude was found to lower levels of inflammatory biomarkers related to heart health. Even if you're naturally a glass-half-empty kind of person, forcing yourself to write a gratitude journal or using an app can deliver results; a common technique is to record 'three good things' a day.

It might even make for fewer jerks. Research last year at the University of Florida found that when employees were encouraged to keep a gratitude journal, they exhibited less rude behavior in the workplace. SF

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"DID YOU KNOW UP TO 40% OF DEMENTIA CASES COULD BE PREVENTED?"

Prof. Anne-Marie Minihane, University of East Anglia

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COMMENT

MORE THAN MEETS THE EYE

How a hand-holding charity stunt launched a social network, way back in the 1980s

On 25 May 1986, 6.5 million people joined hands over 6,638km (4,125 miles) from New York to Los Angeles to do an impossible thing. They were part of Hands Across America, a fundraising stunt to improve awareness about hunger and homelessness in the world's richest country. I was there. We held hands for 15 minutes. It was thrilling.

Hands Across America was organised by a team of people who had their internal threshold of reality skewed by successfully carrying off previously impossible things. The team was USA for Africa, who, a year before, had raised $64m (about £45m) for famine relief with the charity single *We Are The World*. As Marty Rogol, the executive director of USA for Africa, explained to me, "we were probably a little full of ourselves in terms of what we could accomplish."

And so, as a follow-up to the fastest-selling US single of all time (at the time), they orchestrated a human chain across the USA.

There were a few gaps in the middle and it raised far less than the organisers had hoped, but as I discovered recently, it was a surprising success.

To distribute the cash, Rogol hired Bob Greenstein, a poverty policy adviser to President Jimmy Carter. He helped distribute the proceeds, and gave guidelines for what grantees had to do with them – they were to be used for collaboration purposes only.

"On that computer was a service called HandsNet, the first online community for hunger and homelessness groups"

Nancy Berlin ran a homeless shelter in the Los Angeles area known as Skid Row that received a grant. She explained to me that these are the most unusual grants to receive: "If somebody says, 'We're going to give you this money because we want you to talk to each other and strategise about how to end poverty and hunger and homelessness.' Well, then you go, 'Wow, I know that's important. And someone else is telling me that, too.'"

But the shelter didn't just get money. The grant also gave Berlin a computer at a time when few people had them. She did the shelter's book-keeping on it, which freed up time and helped her keep better track of expenses so she could prove to other funders that she and her colleagues knew what they were doing and that they were responsible. But there was even more.

On that computer was a Hands Across America-funded service called HandsNet, the first online community for hunger and homelessness groups. Berlin was HandsNet user number 16 and she was suddenly able to reach out to people, such as attorneys, who she didn't know very well to establish a relationship and begin to form more of a connection. HandsNet still exists today (**handsnet.org**).

On the surface, Hands Across America appeared to be a spectacle. But behind the scenes were folks who knew which people needed to be at the table to tackle the complex issues of poverty and homelessness. Did it solve hunger? No. But for 15 minutes, we held hands across America, and the country was united. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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PORTRAIT: KATE COPELAND ILLUSTRATION: SCOTT BALMER

Listen to Michael's new podcast series *Just One Thing*. Each episode suggests an effective way to improve your wellbeing in one simple step. Available on BBC Sounds.

COMMENT

EAT YOURSELF HAPPY

Increasing evidence suggests that a microbiome-friendly diet is good for your brain as well as your body

The medical profession has taken a long time to accept that what we eat has a big impact not just on our bodies but also on our brains. In fact, one of the earliest studies looking at the impact of food on depression was carried out by Prof Felice Jacka, from the Food and Mood Centre in Melbourne, and she told me it was a real struggle to get patients and to get funding.

For Jacka's study, 67 patients with moderate or severe depression were randomly allocated to either a Mediterranean-style diet or 'social support'. Those allocated to the Mediterranean-style diet were asked to eat more vegetables, fruits, nuts, eggs, fish and olive oil. They cut back on sweets, refined cereals, fried food, fast food, processed meats and sugary drinks.

Despite the relatively small number of people in the trial, after 12 weeks they saw significant differences between the two groups, with 32 per cent of those on the Med diet going into remission (able to reduce medication and no longer considered 'moderately depressed') compared with 8 per cent in the control group. Those who stuck closest to the Mediterranean diet enjoyed the biggest improvement in mood. Since then, several other groups have made similar findings.

So what's going on? Well, some of the components of the Med diet (such as oily fish and the olive oil) have a well-established anti-inflammatory effect, and there is mounting evidence that many cases of depression and anxiety may be linked to brain inflammation. But the foods that make up the Mediterranean diet also boost 'good' bacteria in your gut, and they, in turn, produce their own anti-inflammatory compounds. Foods which have a positive effect on our mood are called 'psychobiotics'.

As part of a new podcast series I've made for the BBC called *Just One Thing*, I interviewed Dr Kirsten Berding Harold, a researcher from University College Cork, who is part of a team who first coined the word, 'psychobiotics'. In one of her most recent studies she asked a group of volunteers to eat what she calls, 'microbiota-friendly food', which included more wholegrains, fruits and vegetables, but also fermented foods like kefir (a form of fermented yoghurt), which are rich in probiotics.

"It really does help your mood and mental health to eat a diet that is microbiota friendly"

Their mood and microbiota were tested at the beginning and end of the study, and there were some impressive changes. Not only did their microbiome change, but as Kirsten explained, "after four weeks on the diet they felt a lot less stressed and had an improved mood. So the preliminary results suggest that it really does help your mood and mental health to eat a diet that is microbiota friendly."

Further support for this theory comes from another recent study by researchers from the University of Surrey. They asked 64 young women to consume either a daily placebo or a capsule containing a prebiotic, a fibre that encourages the growth of 'good bacteria', for a month. At the end of the trial it was those who got the prebiotic capsules who reported the biggest improvements in anxiety levels and who also had better gut health.

More good reasons to improve your diet! SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

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Commander Scott Kelly, shortly after touching down in Kazakhstan in March 2016 after almost a year aboard the International Space Station. He was 5cm taller than when he left

GETTY IMAGES

THROUGH HARDSHIP TO THE STARS

‘Per aspera ad astra’. This is the phrase adopted as a statement of intent by space agencies, both real and fictional, that originates in Virgil’s *Aeneid*. But exactly what kinds of hardship will the human body have to endure to colonise the cosmos? **Prof Christopher E Mason** has been studying astronauts’ reactions to life in space and reveals to **Ian Taylor** how we might adapt to overcome the challenges we face

When Scott Kelly came back to Earth after 340 days in space, it felt like his skin was on fire. Not on re-entry, but later, when he tried to sit down, get dressed or move. Spending close to a year in microgravity will do that to you; aboard the International Space Station (ISS), Kelly’s skin got used to feeling no weight and having nothing touching it.

Like other astronauts, he floated around the ISS with little need for furniture. He didn’t wear shoes and even his clothes drifted around his body instead of hanging from it. So when he came home, a shirt sleeve bearing down on his arm under the pull of Earth’s gravity was alien, painful even. As Kelly himself said in a post-flight press conference: “Adjusting to space is easier than adjusting to Earth…”

Since the year-long mission ended in 2016, Kelly has become a guinea pig for scientists studying what happens to the human body when it ventures beyond Earth’s atmosphere. Even among astronauts he’s a rare case. Not only did he spend the best part of a year in orbit, but Kelly has an identical twin brother, Mark. It gave NASA an unprecedented opportunity to study the physiological, molecular and cognitive effects of long-term spaceflight.

Scott went to space. Mark, the perfect control subject, stayed on Earth. The brothers are both retired astronauts now, but their contributions to the landmark Twins Study continue and have produced a wealth of information about how space affects the heart, the microbiome, the immune system and more.

Learning about the challenges of spending prolonged periods in microgravity is vital as space agencies and private companies get serious about sending humans back to the Moon and even to Mars. A mission to the Red Planet is potentially a three-year trip so we need to understand what might happen to anyone trying to make it.

One of the scientists prodding and poking the Kelly brothers is Christopher E Mason, the lead geneticist on the Twins Study. Mason’s lab at Cornell University is nothing if not ambitious. Its work centres on a “500-year plan for the survival of the human species on Earth, in space, and on other planets.”

“A MISSION TO THE RED PLANET IS POTENTIALLY A THREE-YEAR TRIP, SO WE NEED TO UNDERSTAND WHAT MIGHT HAPPEN TO ANYONE TRYING TO MAKE IT”

As well as studying what happens to astronauts, it involves laying the genetic groundwork for humans to live among the stars. Mason ➤

envisions a future in which the human genome can be bioengineered to adapt to almost any environment, augmented with genes from other species that allow us to explore and settle the farthest corners of the Universe.

Mason is serious. His new book, *The Next 500 Years*, maps out in detail how we'll do it. Here, he gives us a sneak peek…

"REDUCED GRAVITY WREAKS HAVOC WITH THE IMMUNE AND VASCULAR SYSTEMS. THAT'S A CHALLENGE AND THERE'S NOT MUCH WE CAN DO ABOUT IT"

IT'S 500 YEARS IN THE FUTURE. PAINT A PICTURE OF WHAT IT LOOKS LIKE.

So, 500 years from now, we'll have two key things. I call these the twin engines of discovery. [The first is] a good list of candidate exoplanets to go to. In the past 10 years, thousands have been catalogued, including several hundred 'Goldilocks' planets that are probably not too hot, not too cold and that we could possibly survive on. In the next 500 years we'll have, I'm sure, thousands or tens of thousands of other candidates. We could use the intervening time to get better spectroscopy and imaging of the atmospheres to figure out what's there and then pick the best ones.

WHAT'S THE OTHER THING?

The second thing that'll happen is that we'll discover a number of genes in the human genome and other genomes, that we could use to regulate our health, design medical treatments or engineer organisms that could survive a long space flight to another planet and survive on it.

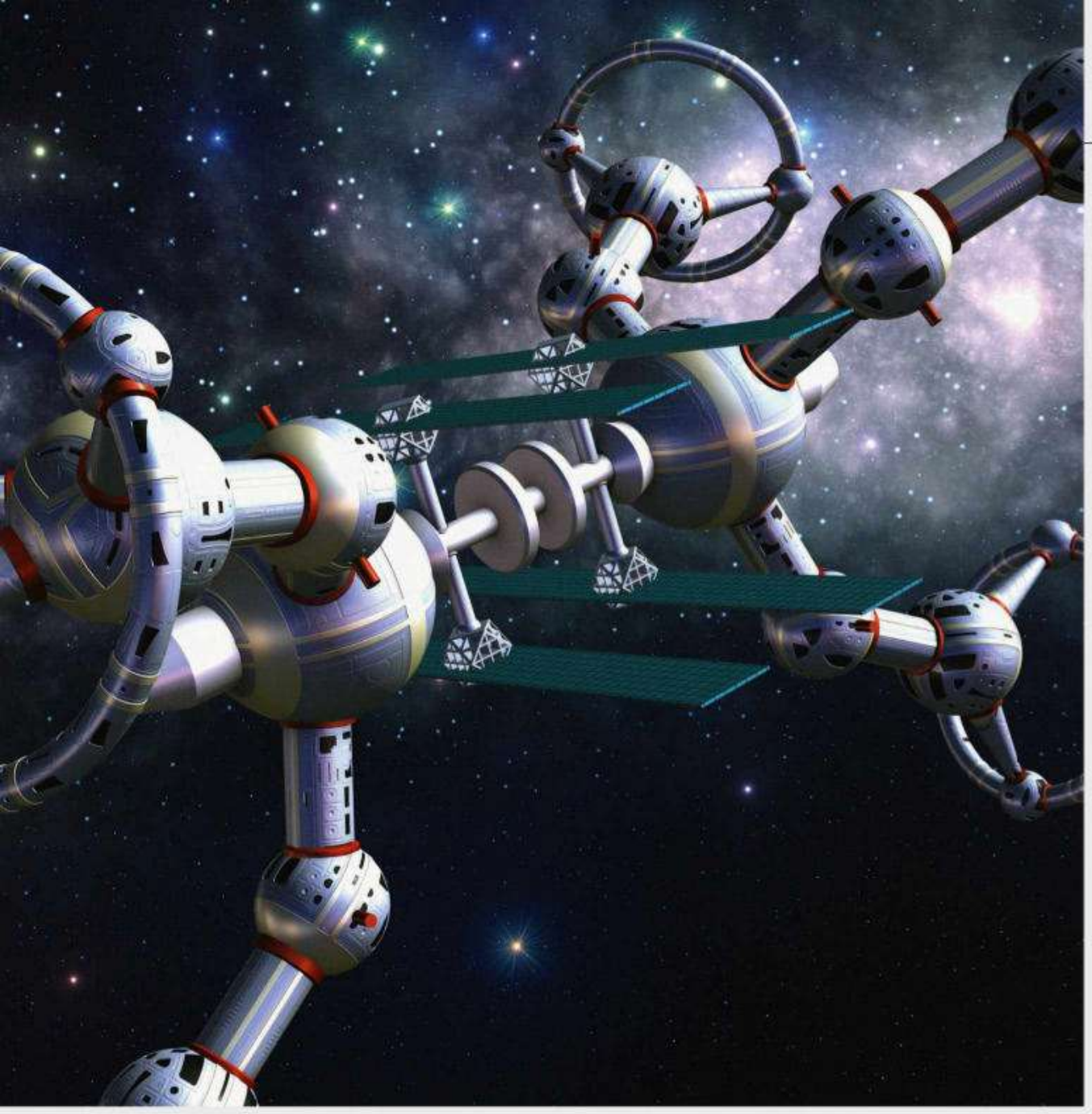
And it's not just for human cells. Microbial cells, of course, would be engineered to produce products, as they do for us now therapeutically. We'll have a genetic tool kit that will let us counteract the ill effects of long-term space travel, and produce the things we need like food and fuel. And, obviously, the more genomes we have in our kit, the more tools we can make.

PRESUMABLY WE'D ALSO HAVE SOME NEW MEANS OF PROPULSION?

At that time, 500 years from now, let's propose that we have generation ships and people

PROF CHRISTOPHER MASON

Christopher is a geneticist and computational biologist who has been a principal investigator and co-investigator of seven NASA missions and projects. He is a professor at Weill Cornell Medicine. As well as preparing human beings for space travel, his research interests include novel techniques for next-generation genome sequencing and editing. He is the author of *The Next 500 Years*.



could live and die in the same spacecraft as they make their way towards one of the new planets. Then we would have humans in more than one Solar System. It would probably take about 20 generations to get there with current propulsion methods. Nowhere in the book do I presume anything new is developed that doesn't already exist today. I'm hoping that'll be wrong. Maybe we'll have a new fusion propulsion that makes it much faster or some way to fold space-time. That'd be fantastic.

BACK IN THE PRESENT, IT SEEMS LIKE WE'RE GETTING SERIOUS ABOUT SENDING HUMANS FURTHER OUT TO SPACE.

Yeah, I'd say it's even hitting a nice acceleration point. If you look at the number of objects that have been sent into space in the past 60 years, it's reached a super exponential pace in the past two years, for sure.

ASIDE FROM THE OBVIOUS, LIKE THE TEMPERATURE AND THE LACK OF AIR TO BREATHE, WHAT MAKES SPENDING A LOT OF TIME IN SPACE SO TOUGH ON THE BODY?

Reduced gravity wreaks havoc with the immune and vascular systems. That's a challenge and there's not much we can do about it. We could have rotating space platforms or magnetic boots like in [the sci-fi show] *The Expanse*, but those aren't really deployed yet. So, there's no way around it. The body does what it can to respond in the short term, though. A lot of [astronauts] have spikes in cortisol, or immune stress signatures. They get up [into space] and their bodies are really reacting. It's very uncomfortable. For the first few days, they often have really sensitive skin. But within a few days they adapt.

WHAT ELSE MAKES SPACE DANGEROUS?

Maybe the most important thing, in terms of health, is radiation – not just in low Earth orbit, but when you get farther out to Mars or on lunar missions. That's really the biggest risk and it's something we can see in the molecular data. We can see indications of the damaged DNA coming out in the urine and we can see it in the blood. You see telomeres [essentially caps that protect the ends of chromosomes from degradation and unnecessary repair] and DNA getting broken. It's the equivalent of about five or six X-rays per day. You can survive it, obviously, because people have been coming back, but, you know, you probably shouldn't have five X-rays a day.

So that's the biggest hazard, the one that NASA and our staff are most worried about. That's why we're spending so much time thinking about pharmaceutical ways to boost radiation-repair mechanisms or even ways of using genes from other organisms that have already adapted to radiation.

HOW HAVE YOU FOUND WORKING WITH THE KELLY BROTHERS? IS IT STILL STRICTLY A WORK RELATIONSHIP OR HAVE YOU BECOME BUDDIES?

For a long time, they were research subjects. During the mission and immediately after, when we were doing a lot of sampling, it was very hands-off. If you're researching subjects you're not supposed to grab a beer with them, much as you might like to. But Scott and Mark are both retired now. They're no longer NASA employees, they're just retired dudes walking around the planet. So we've started to do more together, we're talking about what we've learnt.

I GUESS THAT THEY RETAIN THE CURIOSITY THAT YOU SHARE ABOUT ALL OF THIS.

Yeah, very much. And they're very competitive because they're brothers and astronauts. When we got some of the first genetic sequencing data back, they were emailing me and saying, "Okay, who's got more mutations? Who's got the longest telomeres?" They're competing down to the molecular level. ➤

ABOVE LEFT Astronauts Scott (right) and Mark Kelly are identical twins, but also astronauts. Mark stayed on Earth while Scott spent nearly a year in space

ABOVE Generational ships or new propulsion methods may help us travel deeper into space

BELOW Unpacking fruit or attempting a world record for juggling? In microgravity it's hard to tell the difference

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THE PHYSICAL CHANGES THAT SCOTT'S BODY UNDERWENT, DID THEY LINGER FOR LONG AFTER HE RETURNED TO EARTH?

Some features changed within a matter of hours and days. For example, his telomeres got longer in space, but got shorter within days [of being back on Earth]. He got 5cm taller in space because of the lack of compression of his spinal column. That was gone within minutes.

Other measures like metabolites – pretty small molecules in the blood that can indicate inflammation – some of them were spiking extremely high, like thousands of per cent higher than his baseline before the flight. After two or three days, they went back down again, but it was very painful – his ankles swelled up to the size of basketballs for a little while. Really painful.

HOW DO WE START BIOENGINEERING OURSELVES SO THAT WE'RE BETTER SUITED TO SPENDING TIME IN SPACE?

I think we have to use the evolutionary lessons that every creature has learned as part of our own lesson plan, if you will, for humanity. What I mean by that is other creatures have been surviving in harsh environments. So these different organisms on Earth have found interesting ways to deal with high amounts of radiation, high and low temperatures, salinity. And they serve as, I think, a field guide of adaptation that we can deploy. Say it's a protein that's made by an organism that's resistant to radiation. You can use that as a therapeutic, like the way you grow insulin now. Some cancer therapies and antibody therapies are done this way too.

BUT IT ALSO RAISES THE POSSIBILITY OF HUMAN GENOME EDITING WITH GENES FROM OTHER SPECIES.

Yes. Human genome editing is something you want to do very slowly and very carefully, ideally over multiple generations. I write in my book that there's never been a clinical trial going across many generations. There have been observational studies that have done this. But if we ever do anything to the human genome, really, it would require probably a three-generation study to make sure we didn't screw anything up.

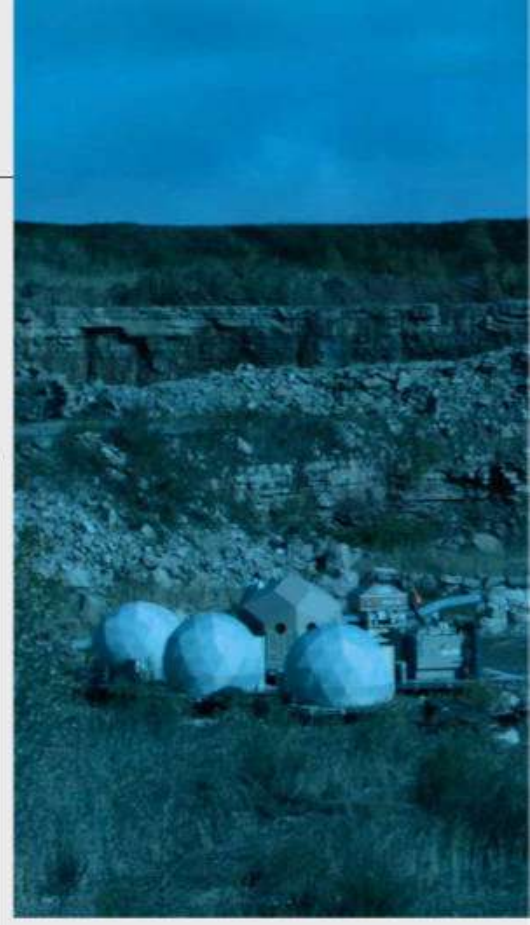
AND IT WOULD ONLY BE AT THE END OF THE THIRD GENERATION THAT WE WOULD HAVE THAT CONFIDENCE?

I would think that if after two generations there are no obvious signs of changes in longevity or disease, or obvious deformities, I would feel at least reasonably safe that we can deploy it for more individuals. This is not something we're going to do in the next five years or even 10 years, although we are engineering cells and infusing them into many patients as we speak.

SO DO YOU HAVE A SHOPPING LIST OF GENES FROM OTHER ORGANISMS THAT YOU THINK, 'WELL, THAT WOULD BE COOL TO HAVE'?

We're in the middle of screening lots of organisms to see which extremophiles can survive either in space – on the ISS, we published the papers of organisms that have adapted there – or just in places on Earth.

We have something called the Extreme Microbiome Project. We're working to categorise all these different sites where we see extreme organisms, like nuclear power



ABOVE Off-world settlements, as portrayed in *The Expanse*, will only be feasible if our bodies can withstand the journey to reach them

"IF WE EVER DO ANYTHING TO THE HUMAN GENOME, REALLY, IT WOULD REQUIRE PROBABLY A THREE-GENERATION STUDY TO MAKE SURE WE DIDN'T SCREW ANYTHING UP"

LEFT Telomeres, the 'caps' on the ends of DNA strands (in yellow), have been found to lengthen while in space, but revert to their normal length once the astronaut has returned to Earth

reactor cooling water, strange places like that. We're still discovering so many organisms. It's a continual process of discovery and the accretion of possible genes.

HOW FAR OFF ARE WE FROM CHERRY-PICKING THESE GENES AND BEING ABLE TO USE THEM EITHER FOR THERAPEUTICS OR ACTUALLY IMPLANTING THEM IN SOME WAY?

For some genes we've already shown that it's working. We have a paper in review now where we've shown it works well with immune cells, at least with genes from tardigrades. But these alien genes being put into humans has not been tried outside of cell cultures, to my knowledge. What has been done, though, is we've also looked at engineered T cells [T cells are a type of white blood cell and are important in the immune system]. You're not modifying all the cells in a person, but you're basically taking out T cells, genetically modifying them and putting them back in for therapeutic purposes. This is actually an extremely common feature of a lot of immunotherapies now.

HAVE YOU WATCHED *THE EXPANSE*?

Yes. I just got the book. I wanted to watch the show first, but I haven't read the books yet.

IT STRUCK ME AS A VIVID IMAGINING OF WHAT A COLONISED SOLAR SYSTEM MIGHT LOOK LIKE. WHAT DID YOU THINK?

I love the concept that humans have a capacity and almost this inevitable future in which we've settled the Solar System. The word 'colony' has fallen out of favour because of all the historical baggage. But I love the concept because I really hope and believe that it will come to pass. The thing I take some issue with is this: it still seems there's been no sociological or intergovernmental advance, we're just as petty and tribal and backstabbing as we are, as we always have been. Maybe it's more accurate. If you look back thousands of years, there's never been a case where cultures have expanded and had a 'Kumbaya' moment and everything's been fine. But I would hope that if we reached that stage [we'd also have] a more advanced philosophical and sociological framework for people. But I might be too optimistic there.

IT WOULD BE NICE IF YOU TURNED OUT TO BE RIGHT.

Yeah, and you get something like *Star Trek*, where all of humanity's united and we're all exploring together. In *Star Trek*, it wasn't until [humans] encountered aliens that humanity kind of nucleated together and said, "Well, we're all in this together."

I GUESS IT RAISES POLITICAL AND ETHICAL QUESTIONS ABOUT SPACE EXPLORATION?

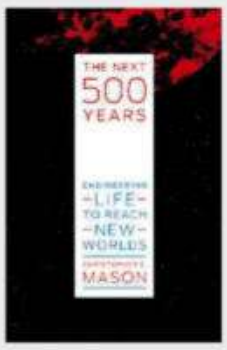
Yeah, something I talk about in the book is this idea of cellular liberty or even planetary liberty. If you're engineering cells you should make it so they can go anywhere you want in the Solar System, or eventually in the Universe. You want to be able to turn on facets of biology that can enable you to live in different places.

ALMOST LIKE A GENETIC OUTFIT TAILORED TO EACH ENVIRONMENT?

Yeah, making it more modular, so you've got that capacity to go places as needed.

ONE LAST THING. DID YOU SEE THE GUY FROM NEUROLINK CAME OUT AND SAID THAT WE HAVE THE TECHNOLOGY TO MAKE JURASSIC PARK. IS HE RIGHT?

Well, you know, there's the Revive and Restore project where we're cloning the woolly mammoth and putting it in elephant embryos. We're working with George Church on that. So that's happening. In that case, we have fully preserved, whole blood cells with a completely intact genome. So if you can get the same thing for a dinosaur, you can give it a shot. In the absence of that, it's going to be really hard. Even with that, it's really hard. I think I'd put it in the unlikely category. But interesting. **SF**



DISCOVER MORE

THE NEXT 500 YEARS: ENGINEERING LIFE TO REACH NEW WORLD *by Christopher E Mason is out now (£25, MIT Press).*

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A GIANT LEAP FOR ANIMAL KIND

As we look to set up permanent bases on the Moon, Mars and beyond, we'll need to bring other forms of life with us... but how will they cope with life in space?

WORDS **CHRIS BARANIUK**

The thousands of space travellers were in suspended animation and nestled together on their ship, which was about to land on the Moon. But something was wrong. The ship's computer initiated a series of commands that accidentally shut down its engines. As the craft careered towards the lunar surface, its passengers lay silent and still, oblivious. The impact was powerful. Dust scattered.

And yet, they may have survived. The creatures on board that doomed vehicle were tardigrades, also known as 'water bears' – micro-animals that can endure extreme temperatures, pressures and even radiation, among other harsh conditions. If they did make it alive, they would have achieved something rather special. Hardly any animal species has ever made it so far from Earth.

The botched landing, which happened in 2019, was not necessarily catastrophic enough to destroy the tardigrades, according to the Arch Mission Foundation, the non-profit that decided to send the tardigrades to space. The organisation had attached the creatures to a stack of discs containing information about human civilisation, which was aboard the lunar lander. But unless humans or perhaps robots can investigate the crash site, potentially many years from now, we won't know for sure, says Doug Freeman, a spokesperson for the foundation. "It's actually unlikely that the disc would have been destroyed," he adds.

Crucially, the tardigrades were in a state of dehydration, which suspended their metabolisms. In theory, the creatures could be reanimated years after the crash, should they have survived intact. The mission, called Beresheet, was the first Israeli mission to land on the Moon. No other animals, as far as we know, have spent so long on the lunar surface.

> **"As humans establish outposts, bases or research stations on the Moon, then we might bring with us life forms other than ourselves"**

COLONISING THE MOON

In the past, many people assumed that the Moon was populated with creatures, like the Earth was. There's an old folk belief that the woodcock, a rarely seen ground-nesting bird, spent its summers on the lunar surface because it always returned from migration on the first full Moon of November. And the Greek philosopher Philolaus was among those who thought lunar animals must be 15 times larger than those on Earth. For some reason he also argued that they did not produce poo.

Today, we think of the landscape of the Moon very differently. It is considered more or less barren. But that could change. As humans establish outposts, bases or research stations on the Moon, we might bring with us life forms other than ourselves (and the microbes that live on and in our bodies). In other words, the tardigrades could soon have company. From providing food to ➤

GETTY IMAGES

acting as our personal companions, animals could have important roles to play on the final frontier. And we might even find novel ways of benefitting or safeguarding the nature of planet Earth as we explore the Solar System and beyond.

"My feeling is that we can't go into space alone," says Cyrille Przybyla, a researcher at the French Research Institute for Exploitation of the Sea. "We have to keep with us our environment."

Przybyla is one of a few researchers who are convinced that the future of human spaceflight will feature plants, animals and other organisms. He points to the 1972 film *Silent Running*, in which giant spaceships with greenhouse-like domes preserve a collection of plant and animal species in a future era when Earth's forests have almost gone extinct. The film's story is not the most compelling, argues Przybyla, but the idea of taking this bounty of biological life with us into space, is. "My vision is close to this bad movie," he says.

Przybyla's current project, the Lunar Hatch Programme, involves fish eggs. In a series of experiments, he and his colleagues have shaken, vibrated and accelerated fish eggs (from sea bass) to great extremes to see whether larvae will still hatch from them after enduring such punishment. The idea is to simulate the effects of a rocket launch and spaceflight. In some of the latest experiments, the results of which have not yet been peer-reviewed, the eggs were exposed to acceleration up to 5g using a rapidly spinning machine. A separate machine was used to expose the eggs to simulated microgravity, such as they might experience on a voyage to the Moon in the future. Should fish eggs be able to withstand the mechanical stresses of spaceflight, they could one day be conceivably delivered to a future Moon base, and hatched in an aquaculture system using water retrieved from below the lunar surface. Przybyla argues that fish could be a vital source of protein for lunar residents and a reminder of the appetising food they must leave behind on Earth.

FLYING FISH

So far, the fish eggs appear robust enough to survive the physical strain of flying to the Moon. But the next step, says Przybyla, is to expose them to radiation to see whether that reduces the hatching rate. He's reasonably confident that the eggs will survive. If so, it might be thanks to evolutionary toughness. Przybyla points out that when the first aquatic life evolved on Earth more than three billion years ago, there was little or no atmosphere and so those early organisms might have been exposed to more cosmic radiation than terrestrial species today.

Should the Lunar Hatch Programme continue to prove successful, the project might become part of the European Space Agency's (ESA) Moon Village in the coming decades, potentially paving the way for fish farming on the Moon. There are no guarantees, though. The proposal is currently one of around 300 vying for inclusion in the Moon Village programme.

Przybyla says he decided to focus on fish partly because they are relatively small animals that don't produce excessive amounts of CO_2. Waste products would have to be disposed of or recycled on an ultra-efficient Moon base, since space will be so

ESA/ALEXANDER GERST, NASA

ABOVE
Astronauts on the ISS already grow fresh salad leaves to supplement their diet. Here, Serena Auñón-Chancellor harvests kale and lettuce for Thanksgiving

LEFT With a growing population on the Moon, it would not be feasible to ship food from Earth. There are plans to test how plants fare when grown in space, as seen in this illustration

limited and the environment will have to be kept clean and safe. For similar reasons, insects could also be part of a lunar farm one day, argue the authors of a 2020 report from the University of Australia and the International Space University. "Insect farms require relatively small amounts of space and lower water usage when compared with conventional meat protein sources on Earth," they write, before suggesting some specific candidates – crickets, silkworm pupae or palm weevil larvae.

Even the small environmental footprint of these animals makes the idea of rearing them on the Moon problematic, at least in the near future, argues Dr Christophe Lasseur, from ESA's Life Support and Physical Sciences Instrumentation Section.

"Animals will consume oxygen, they will produce CO_2... they will produce faecal matter," he says. "We are more looking to plants, bacteria and microalgae."

ESA's Melissa programme is working on the design of a 'closed-loop' system to provide lunar inhabitants with food, perhaps in the form of spirulina, a blue-green algae that has long been harvested as a food source in Africa and Latin America, and which turns carbon dioxide into oxygen.

> "While delivering food direct from Earth might suit at first, it's not something that would be practical indefinitely"

The debate on whether it will be necessary to raise animals on the Moon to provide food rests on factors such as whether protein will be more easily obtained from other sources and whether it might just be easier to ship food directly from Earth. That is how the International Space Station (ISS) occupants get their food – save for a few salad leaves grown in space.

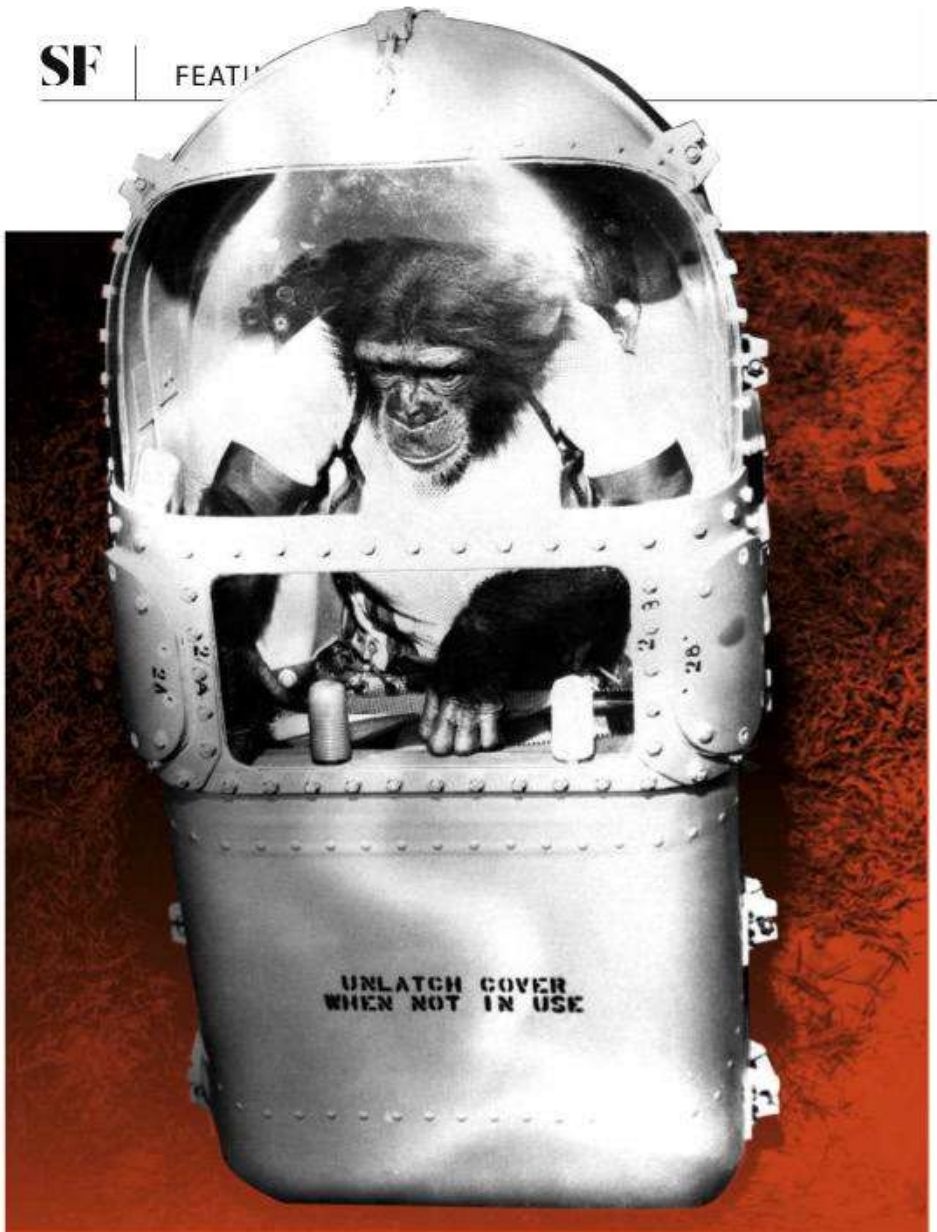
WHAT'S FOR DINNER?

But Dr Martina Heer, professor in nutrition physiology at the University of Bonn, points out that human beings need a few kilograms of food per day. Supplying a cadre of lunar residents with constant deliveries might actually be prohibitively expensive. "That's a lot of weight you have to take to the Moon," she says.

So while delivering food direct from Earth might suit at first, it's not something that would be practical indefinitely, especially once the number of people living on the Moon grows, says Dr Mike Dixon, professor and director of the Controlled Environment Systems Research Facility at the University of Guelph in Canada.

Dixon has spent years researching how well plants can grow in space. Shortly, he hopes to monitor an experiment on the ISS to see whether barley will grow when exposed to cosmic radiation. And he also has plans to grow barley on a lunar lander in the future, too.

"The psychological appeal of the food you eat is not to be discounted," Dixon says, arguing that fish and insects are among the top candidates for lunar livestock. While some may not leap at the chance to gulp down a bowl of crickets, it's possible to grind dried insects into powder and use them in various recipes that have no hint of antennae or spiny legs.



A HISTORY OF ANIMALS IN SPACE

Animals were used repeatedly in the early days of the space race. The Soviet Union sent dogs into space on multiple occasions. The first hominid in space was Ham, a chimpanzee who took a suborbital flight in 1961 as part of the US Project Mercury programme. But very few non-human animals have made it as far as the Moon. In 1968, the Soviet Zond 5 mission transported two tortoises and some fruit fly eggs on a voyage that circled the Moon and returned safely to Earth. Four years later, five mice – nicknamed Fe, Fi, Fo, Fum and Phooey, circled the Moon 72 times on the US Apollo 17 mission. As the space race progressed, animals participated less, says former chief historian at NASA, Dr Roger Launius. This is because the main purpose of using them was to establish whether spaceflight would be safe for humans. "By the time that we're going to the Moon, we've learned enough to know that we can build a spacecraft that the astronauts can survive in, assuming nothing goes wrong," he says.

Besides the tardigrades, which may have survived the Beresheet crash in 2019, there is a small possibility that silkworms hatched on the Moon in recent times. In early 2019, a Chinese lunar lander, Chang'e 4, successfully brought silkworm eggs to the lunar surface. At the time of writing, *BBC Science Focus* was unable to find any public information about the fate of the eggs. The China National Space Administration and researchers behind the mission did not respond to requests for comment.

"Companionship in the form of animal pets could help boost the wellbeing of people housed in a tiny Moon base"

Will all lunar animals just end up being eaten by humans? Not necessarily. Dr Nancy Gee, professor of psychiatry at Virginia Commonwealth University, argues that any human who stays on the Moon for more than a few days will have to battle feelings of loneliness, being so far from their home planet and in such a desolate place.

"I imagine that it might feel very dislocating, very isolating," she says. To remedy this, companionship in the form of animal pets could help boost the wellbeing of people housed in a tiny Moon base. There's lots of research to suggest that interacting with animals such as dogs can improve people's moods and lower stress levels, says Gee.

If Fido is too big an animal to accommodate on the first Moon bases, even insects could help, potentially. One randomised, controlled trial in South Korea found that looking after crickets resulted in significantly lower feelings associated with depression in older people, compared with not having the insects to tend to at all.

Ultimately, taking animals on long voyages into space to sterile environments will be an ordeal. Gee argues that we should do our best to ensure that such activity is ethical. But incorporating animals and nature more widely into space exploration need not only be about serving human needs. It might just be possible to give something back to nature too, by finding ways of preserving or protecting it in space.

As if in further homage to *Silent Running*, there are plans afoot to safeguard fragments of the natural world in space, for real. Dr Jekan Thanga, assistant professor of aerospace and mechanical

ALAMY, SHUTTERSTOCK, UNIVERSITY AUTONOMA BARCELONA/ESA

engineering at the University of Arizona, says that lava tubes, formed billions of years ago when the Moon was volcanically active, could provide the perfect storage space for millions of seeds, spores, sperm and eggs – a lunar ark that would act as a stockpile of the basic materials we'd need for rebuilding Earth's ecosystems from scratch.

"It could be a site for backups – backups of the stuff that we most value," says Thanga. "From our point of view, that would be the biodiversity of Earth."

It would take around 250 rocket launches, given the size of current vehicles, to transport all the required biological material to the Moon for storage. And once there, it would have to be placed into the lava tubes and refrigerated to a temperature of -180°C or lower.

Thanga says the value of this wouldn't just be in having backups from which to replenish life on Earth, should it disappear, but this material could also potentially be used to populate other celestial bodies with life from Earth, as human beings travel further into space and establish themselves on other worlds.

This all brings gigantic challenges. Seeds and eggs aren't the only things required for establishing an ecosystem. Any off-world replica of Earth would also need suitable growing media for plants, enough water, oxygen, light and heat – and the materials that plants and animals need to grow or reproduce. These details are yet to be sketched out in full, says Thanga.

But the basic principle that human space exploration ought not to be a totally sterile endeavour could lead to this project and others becoming reality one day – from fish farms on the Moon to pet dogs travelling with us across the stars.

ABOVE LEFT In the film *Silent Running*, plant and animal life from Earth is safeguarded in space. Similarly, some scientists have hypothesised that lava tubes on the Moon could store seeds, spores and eggs to rebuild Earth's ecosystems

ABOVE Scientists at ESA's Melissa programme are developing a closed-loop system where waste is recycled and astronauts are provided with food and oxygen

As Lasseur says, bringing lots of animals with us will not be realistic at first. Humans on the Moon, Mars or further afield will be like those stationed at Antarctica today – more or less cut off from much of the environment that they are used to. But after that, who knows?

Researchers like Przybyla argue that maintaining a link with the biodiversity of Earth, the planet we came from, will be crucial for future explorers and space pioneers. Gee makes a similar point, suggesting that it's now time for us to start asking questions about how we could take animals with us.

"How can we continue to keep animals as part of our lives, even when we're no longer on Earth – how can we continue to include them? Because they are so important to so many people," she says. **SF**

—

by **CHRIS BARANIUK** *(@chrisbaraniuk)*
Chris is a freelance science journalist based in Northern Ireland.

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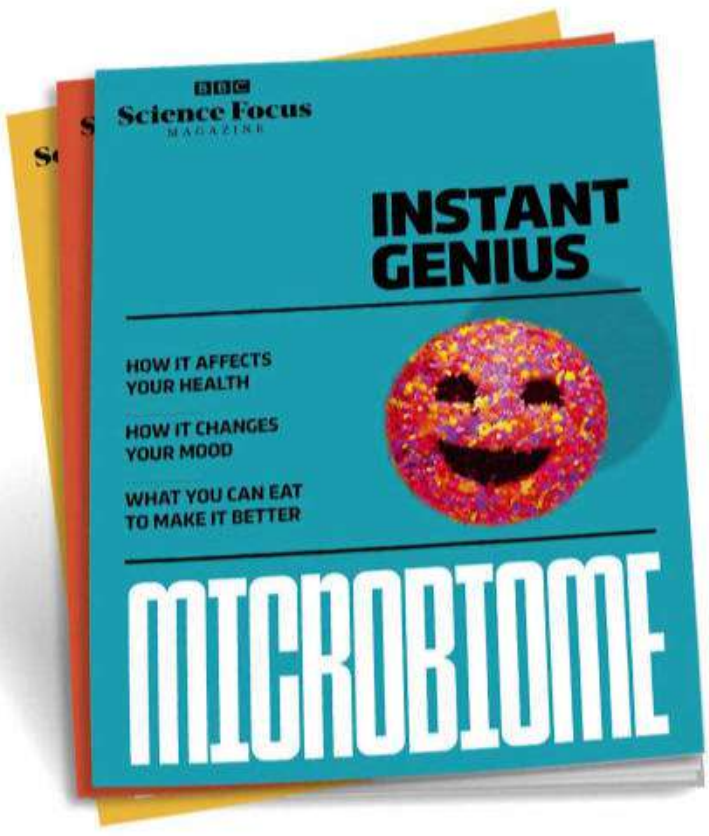

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... DOES SOUND GENERATE ANY HEAT?
... WHY DON'T IDENTICAL TWINS HAVE IDENTICAL FINGERPRINTS?
... CAN YOU DIE LAUGHING?
... DO ANIMALS EXERCISE?
... HOW DO BEES MAKE HONEY?
... IS IT POSSIBLE TO INCREASE MY IQ?
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ILLUSTRATION: DANIEL BRIGHT

IS IT DANGEROUS TO WAKE A SLEEPWALKER?

When someone is sleepwalking they'll move out of bed and show complex behaviours while lacking high-level cognition (such as planning). They're also likely to have their eyes open and may be staring vacantly, which can be disconcerting to anyone they encounter.

Sleepwalking, also known as somnambulism, involves a partial arousal from deep sleep. This typically occurs during the Non-Rapid Eye Movement (NREM) stage of sleep. This type of sleep predominates during the beginning of the night, which is why sleepwalking typically happens at this point.

Children are more likely than adults to sleepwalk due to the composition of their sleep. Overall prevalence rates of sleepwalking vary widely, but one meta-analysis estimated as many as 7 per cent of people sleepwalk.

As to whether it's dangerous to wake a sleepwalker, it's not advisable to do this forcefully as this could lead to disorientation or even a violent response from the sufferer. However, in certain circumstances, it may be appropriate to gently wake someone who has completed a sleepwalking episode and let them fall back to sleep again in order to prevent them from moving straight back into another sleepwalking episode.

If you discover a sleepwalker, rather than waking them, you might want to calmly lead them back to their bed in order to help ensure their safety. ***AGr***

TOP TEN

COUNTRIES WITH INCREASING FOREST AREAS

Deforestation is a growing, human-made calamity. Over 47,000 km² (an area almost twice the size of Wales) of forest is lost worldwide annually. In fact, 17 per cent of the Amazon rainforest has been destroyed in the past 50 years alone. But some countries have recently logged surprising increases in forest space. Here are the top nations with the highest net gain of woodland per year:

1. China — **19,370**km²

(An area over ***12 times*** the size of ***London***)

2. Australia — **4,460**km²

(***16 times*** the size of ***Birmingham***)

3. India — **2,660**km²

(***61 times*** the size of ***Luton***)

4. Chile — **1,490**km²

(***25 times*** the size of ***Dundee***)

5. Vietnam — **1,260**km²

(***Nine times*** the size of ***Cardiff***)

6. Turkey — **1,140**km²

(***35 times*** the size of ***Slough***)

7. USA — **1,080**km²

(***23 times*** the size of ***Exeter***)

8. France — **830**km²

(***15 times*** the size of ***Bolton***)

9. Italy — **540**km²

(Over ***four times*** the size of ***Belfast***)

10. Romania — **410**km²

(Almost ***eight times*** the size of ***Norwich***)

SOURCE: *Food and Agriculture Organization of the United Nations*

NIBAL SAWAF, CARDIFF

WHY DOES BAMBOO GROW SO FAST?

Bamboo is the fastest-growing plant on Earth. In fact, the Chinese moso bamboo can grow almost a metre in a single day.

Bamboo grows in dense forests where little light reaches the ground and there is strong evolutionary pressure to reach the sunlight as quickly as possible.

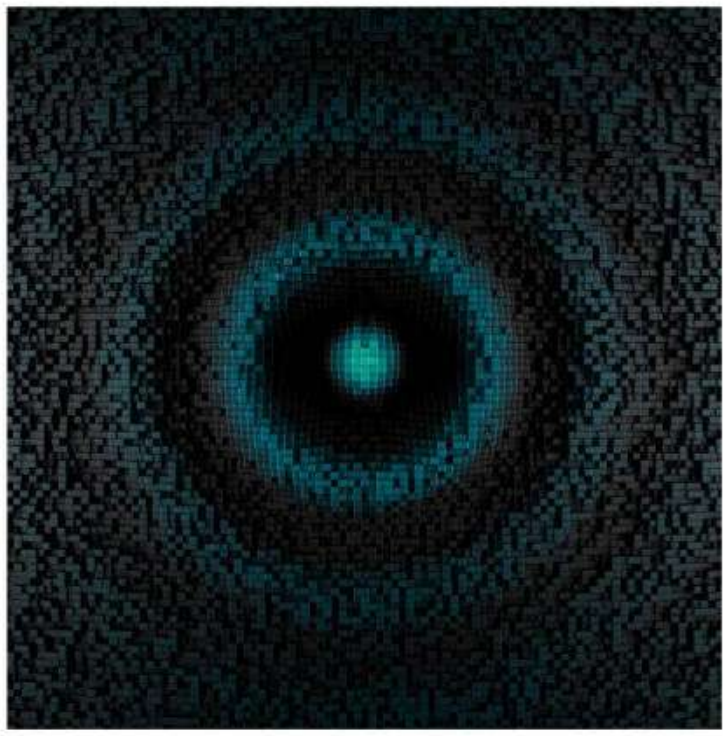
Bamboo shoots are connected to their parent plant by an underground stem, called a rhizome. This means the shoot doesn't need any leaves of its own, until it reaches full height. Bamboo also grows with constant diameter. Unlike woody plants, bamboo doesn't waste energy on growth rings that progressively thicken the stalk. It's just a single stick, growing straight up. *LV*

ADAM KING, HUDDERSFIELD

WHY IS AMBER SO GOOD AT PRESERVING LIFE?

You could say that amber preserves death. Amber is essentially fossilised tree resin – certain trees exude sticky, antiseptic resin to protect their bark from bacteria and fungi. As it leaks out of the tree, the resin can also trap any unfortunate creature in its path, preventing decay with its antiseptic nature and a lack of water.

In a similar process to the reactions used to form plastics, the resin hardens when some of its organic molecules bond together to create bigger ones. This hardened resin, what we call amber, can survive intact for hundreds of millions of years. ***ED***



JENNI CHATER, BOURNEMOUTH

DOES SOUND GENERATE ANY HEAT?

Yes, sound can generate heat. In fact, it practically always does, though the amount is generally too small to notice.

Sound and heat are different kinds of motion of atoms or molecules. Sound is an orderly motion, while heat is randomised. If atoms are squeezed close together at some point (maybe by a loudspeaker), they'll bounce away from each other and, in turn, squeeze nearby atoms together. This leads to a wave of high-density peaks and low-density troughs, which we perceive as sound. As the wave travels, or hits objects, this orderly motion is disrupted and randomised, becoming heat. ***JB***

GETTY IMAGES X2, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: DANIEL BRIGHT

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

MY BELLY BUTTON SMELLS LIKE A RUBBISH TIP. IS THIS NATURAL?

Your belly button has its own tiny, thriving ecosystem that may be home to more than 100 types of bacteria, according to one major analysis (although the average is around 60 types).

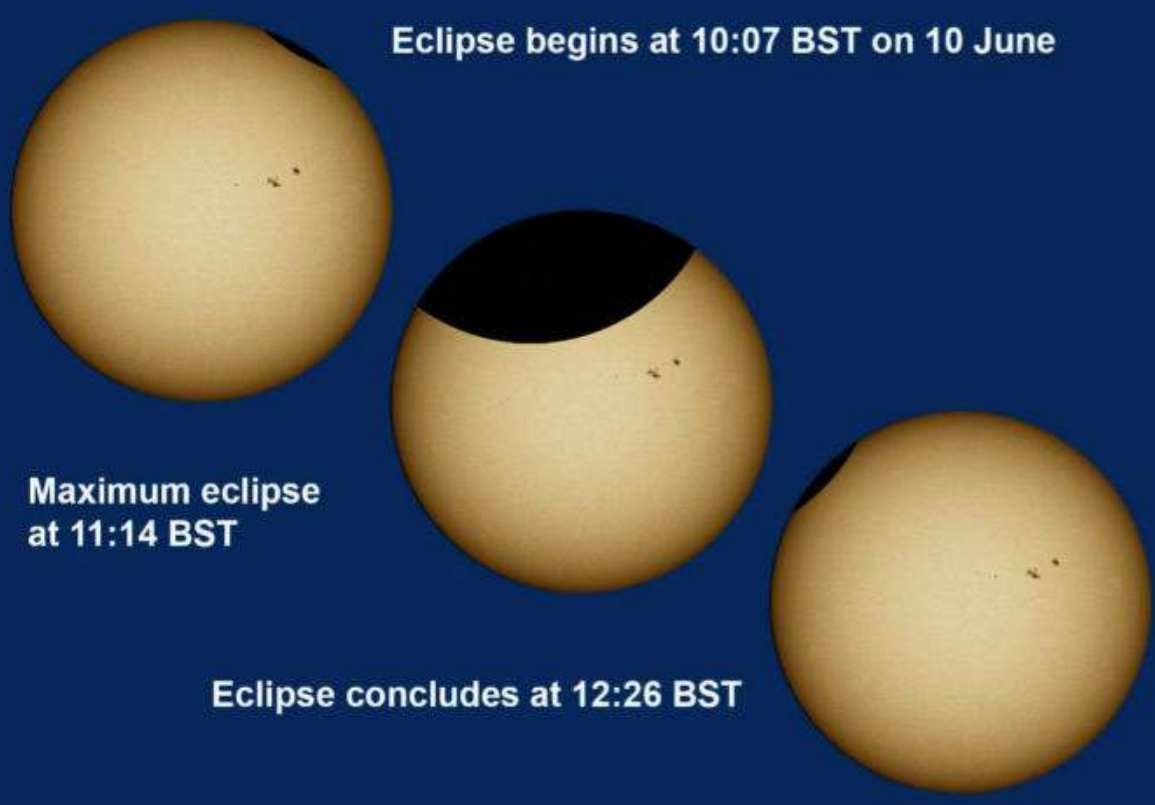
Why so many? Well, if you think about it, your navel is an attractive place for bacteria to hang out: comfortable folds of skin, not much air to whip them away – and they're often undisturbed because we don't always clean inside it regularly.

Most of the time they stay in low numbers. But if the bacteria are given a chance to multiply, they can get out of control. This is even more likely to happen if you have an 'innie', or if you have a piercing (the perfect cavity to house some unwanted guests). It's the abundance of bacteria, along with the sweat, grime and fluff that can collect there, that could give your belly button a bit of a whiff.

But don't worry – it's easy to sort. A quick clean with soap during your normal shower can usually eliminate any odours. But don't use moisturiser – aggressive cleaning and excess moisture can also encourage bacterial growth.

Next time you're navel-gazing, imagine all the little organisms feasting in there and take a moment to send them packing. ***NM***

ASTRONOMY FOR BEGINNERS



Times correct for the centre of the UK and vary slightly with location. From the UK, maximum eclipse appears largest from the northwest of Scotland, extending halfway across the Sun. From southeast England, the Moon extends over 30 per cent of Sun's diameter.

ALL YOU NEED TO KNOW ABOUT JUNE'S SOLAR ECLIPSE

WHEN: 10 JUNE

On 10 June, people around the world will be treated to the biggest partial solar eclipse since 2015. Such an annular solar eclipse happens when the Moon's shadow covers most of the Sun, leaving only a red ring or 'annulus' (Latin for 'ring') visible. This happens when the Moon moves between Earth and the Sun, blocking most (but not all) of the star's light from reaching our planet.

The Moon doesn't orbit Earth in the same plane as Earth orbits the Sun. If it did, we'd have a solar eclipse every lunar cycle. Instead, the Moon's orbit is tilted, its path only coming between Earth and the Sun during a period called eclipse season, which happens usually twice a year and lasts about 34.5 days.

The type of solar eclipse that happens during this time depends on where the Moon is in its elliptical orbit. If it's at its closest point to Earth (called perigee) it can block out all the Sun's rays, creating a total eclipse. But if it's at or near its furthest point (called apogee) it leaves a red ring, creating an annular eclipse.

The eclipse will look different around the world. Only viewers in Greenland, northern Canada and northeastern Russia will see this red ring. In the UK, viewers will see part of the Sun eclipsed. The further north you are, the more you'll see, with the north of Scotland witnessing over 30 per cent of the Sun eclipsed, compared to only 20 per cent in London.

To watch the eclipse, make sure to use solar safety glasses or an eclipse viewer, and never look directly at the Sun without protection. In the UK, the eclipse will begin at 10.07am and reach its maximum at 11.14am. ***AB***

ELEANOR WARNES, BOLTON

WHY DON'T IDENTICAL TWINS HAVE IDENTICAL FINGERPRINTS?

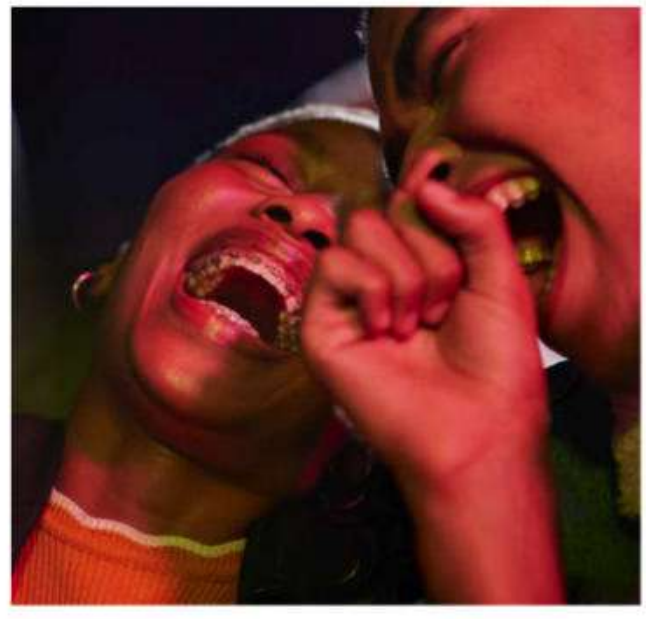
In the late 1800s, doctors and scientists began gathering evidence that the pattern of ridges on a person's fingers is not only unique to them, but also stays the same throughout their life, making fingerprints useful for identification. It wasn't long before fingerprints were being used to catch criminals and they remain an important forensic tool today.

SARAH STORRS, BELFAST

CAN YOU DIE LAUGHING?

Yes, it is possible to die from laughing, but don't let this stop you enjoying your favourite sitcom. There are just a handful of reported cases, usually due to intense laughter causing a heart attack or suffocation.

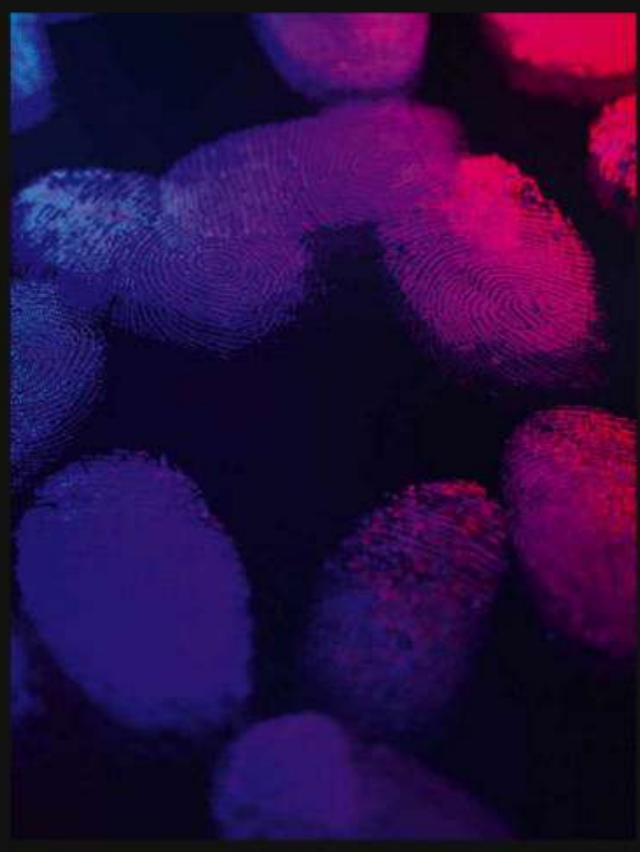
People have also been known to faint from laughing, which can lead to injuries, and some narcolepsy sufferers report temporary losses of consciousness triggered by laughter or other strong emotions. There are some very rare fatal brain conditions that can cause uncontrollable laughter. ***CA***



The likelihood of two people sharing identical fingerprints by chance is estimated to be less than one in 64 billion. Based on those odds, researchers have calculated that it would take more than a million years for two people with identical fingerprints to appear by chance in Scotland Yard's fingerprint database.

Even identical twins – who have the same DNA sequence and tend to share a very similar appearance – have slightly different fingerprints. That's because fingerprints are influenced by both genetic and environmental factors during development in the womb.

Fingerprints are set between 13 and 19 weeks of foetal development. The precise details of the whorls, ridges, and loops are affected by many factors, including umbilical cord length, position in the womb, blood pressure, nutrition and the rate of finger growth. Those small differences can become more pronounced after birth as a result of differences in weight and height, for example.



So, although their shared DNA means identical twins' fingerprints do tend to be more similar than those of strangers, forensic experts and state-of-the-art recognition software can still spot the difference, making it harder than you might think for twins to become criminal masterminds.

But fingerprints are not unique to humans. Chimpanzees and gorillas also have fine ridges on their fingertips that seem to be unique to individuals, which we probably inherited from a shared ancestor. Plus, a more distant relative, the koala, has independently evolved fingerprints that are surprisingly similar to ours. ***CA***

CROWDSCIENCE

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Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

DO ANIMALS EXERCISE?

Most animals are physically active. They fly, walk, swim and slither to discover food, flee predators and find mates, but exercise is more than this. It's any form of voluntary physical activity that goes beyond this baseline level. Often, there's a motivational component. Humans, for example, exercise to prepare for feats of endurance, stave off disease or impress a partner. Some even say they enjoy it.

With non-human animals, it's harder to ascribe intent, making the question of 'do animals exercise?' a tricky area of research. It's difficult to know whether a behaviour is voluntary or something that occurs as a necessary part of survival.

Take play. Wolf cubs wrestle, chase and ambush their littermates, which leads to better hunting and fighting skills. But is it exercise? The jury is out.

I once had a hamster who ran so furiously on his wheel, he clocked up more revolutions than Che Guevara. Brain chemistry experiments show that domestic hamsters derive pleasure from the practice, so when he died at the wheel, at least he was happy.

Annoyingly, some animals don't even need to exercise to get fit. Before they migrate, barnacle geese develop stronger hearts and bigger flight muscles just by sitting around eating. It's thought an environmental cue triggers the change, so if someone ever berates you for being a couch potato, just tell them you're channelling your inner goose. *HP*

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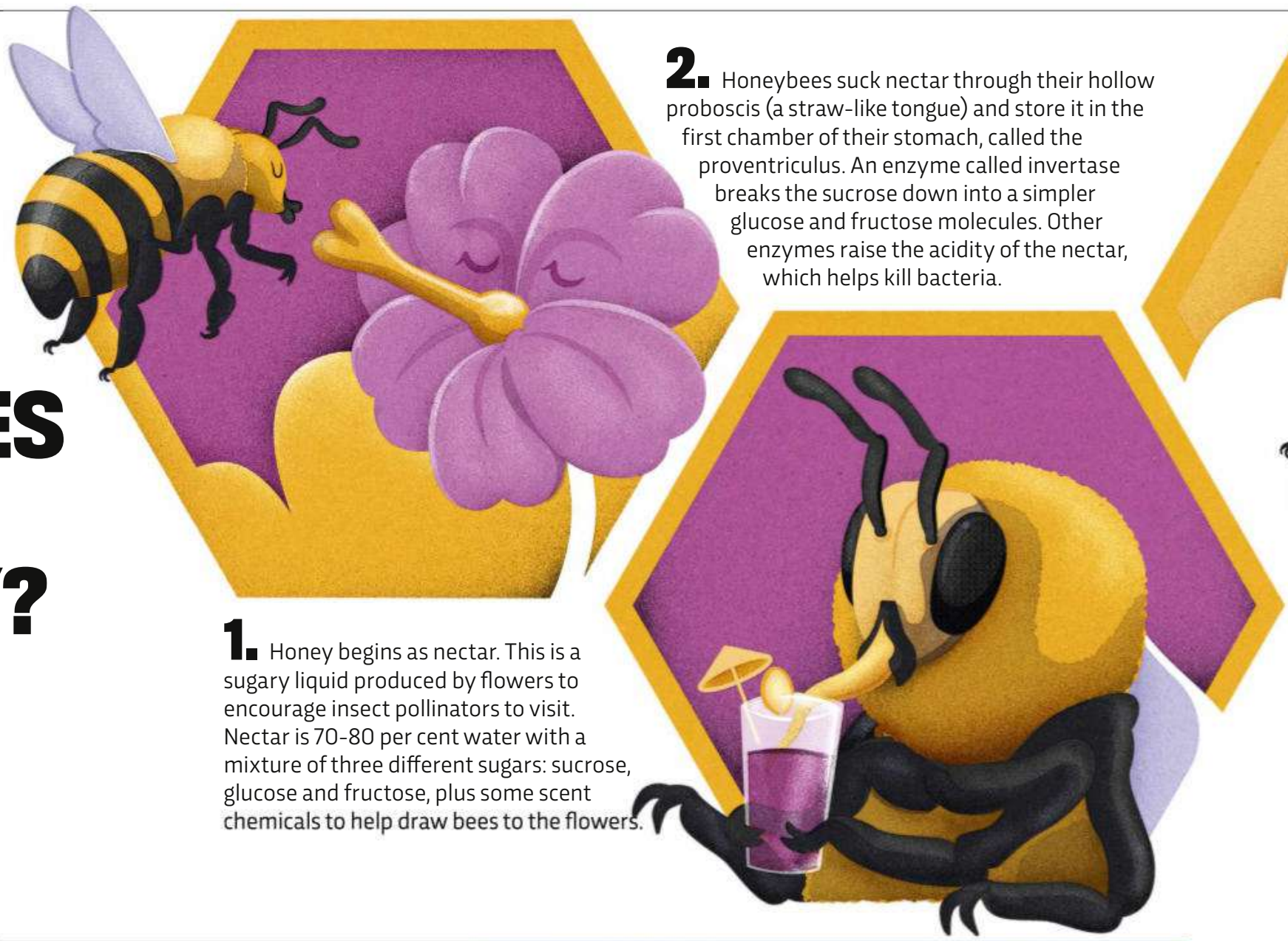
HOW DO BEES MAKE HONEY?

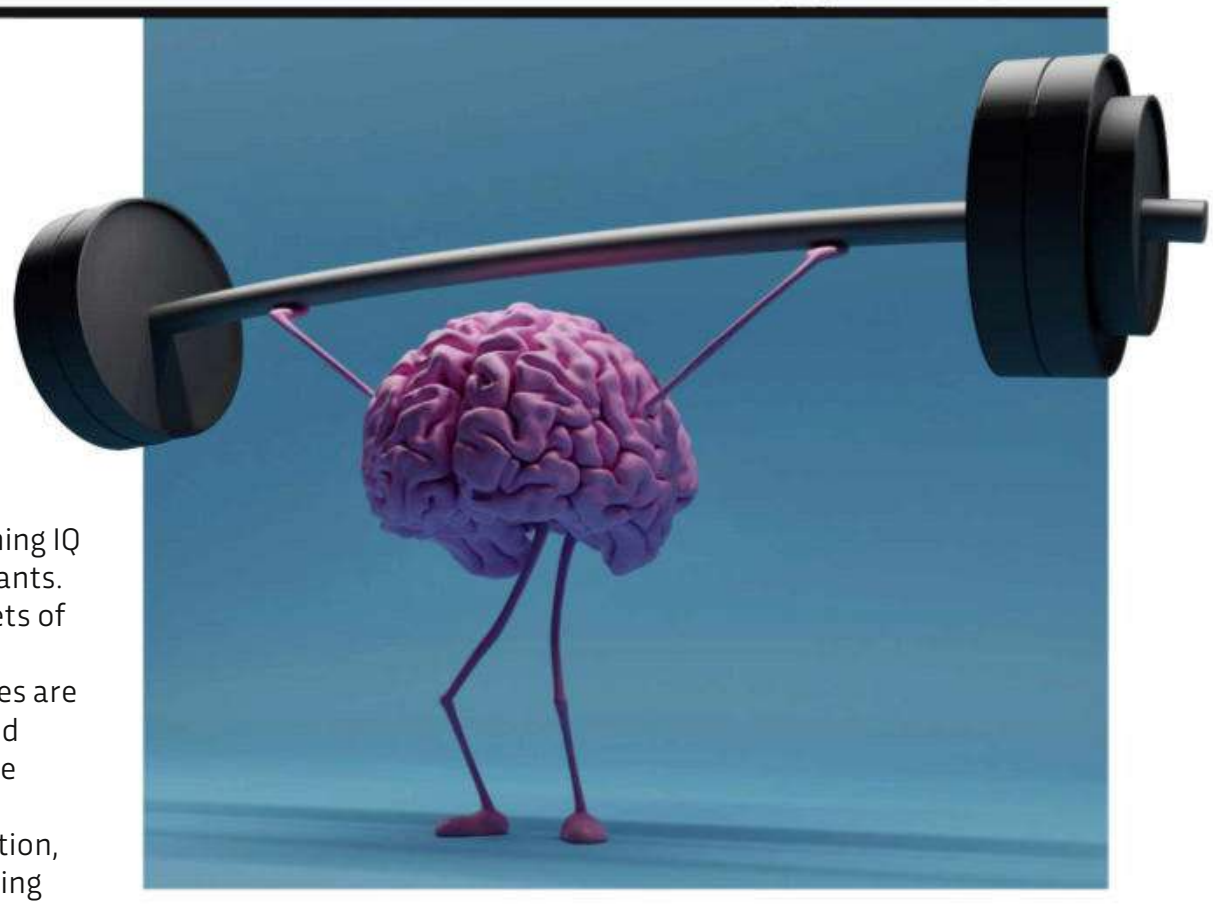


1. Honey begins as nectar. This is a sugary liquid produced by flowers to encourage insect pollinators to visit. Nectar is 70-80 per cent water with a mixture of three different sugars: sucrose, glucose and fructose, plus some scent chemicals to help draw bees to the flowers.

2. Honeybees suck nectar through their hollow proboscis (a straw-like tongue) and store it in the first chamber of their stomach, called the proventriculus. An enzyme called invertase breaks the sucrose down into a simpler glucose and fructose molecules. Other enzymes raise the acidity of the nectar, which helps kill bacteria.

MICHAEL HUSKINS, MANCHESTER

IS IT POSSIBLE TO INCREASE MY IQ?



Short answer: probably not. But it's not just you.

Coined in Europe in 1912, IQ (intelligence quotient) was designed as an objective score to identify those requiring educational help. Although perhaps well-intentioned, many scientists have called into question its validity, with some claiming IQ tests are inherently biased in favour of white, Western participants. Others have claimed IQ doesn't take into account the many facets of intelligence, such as social, musical and mathematical ability.

Whether valid or not, one thing is clear: IQs in several countries are increasing. Scores across western European countries, Japan and South Korea rose an average of three points per decade until the 1990s. Known as the 'Flynn Effect' (named after intelligence researcher James Flynn), experts ascribe this to improved nutrition, better schooling, fewer infectious diseases and a more stimulating environment.

However, actively working towards increasing your IQ is not easy. One long-term study found that it took five years of intensive intervention in infancy to increase IQ by only a few points.

But if you want to increase all-round intelligence rather than IQ, there may be more scope. Although not identifying direct causal links, an Imperial College London survey of over 250,000 people found that those who read a lot scored more highly for verbal intelligence and gamers scored more highly for working memory.

The most effective known intelligence booster? Exercise. A University of South Wales study suggested that aerobic exercise can increase levels of brain-derived neurotrophic factor, a hormone essential for new brain cells and connections. Similarly, a University of British Columbia study suggests that regular aerobic exercise boosts the size of the hippocampus, the brain area involved in verbal memory and learning.

While the jury's out on whether attempting to increase your IQ is worth it, you might just find increased exercise, reading and gaming are ultimately more rewarding than a number on a scale. ***LS***

4. Back at the hive, forager bees regurgitate the nectar. It's then passed between worker bees, mouth-to-mouth, to reduce its water levels. Once the water content drops to 18 per cent, mould and bacteria can't grow and the nectar becomes honey, which the worker bees push into wax chambers.

3. Bees can carry up to half their body weight and have one of the highest power output rates in the animal kingdom. This lets them forage up to 5km from the hive, but at this range most of the nectar payload is used for the flight home.

5. In spring and early summer, the bee colony uses all its honey to feed the larvae, building its workforce to a summer peak of 50,000 bees. These workers then spend two to three weeks madly gathering nectar to last the winter. It takes 12 bees their entire life to make a teaspoon of honey. ***LV***

QUESTION OF THE MONTH

IAN HOLDEN

DOES ANYONE CONTROL WHERE SATELLITES ARE LAUNCHED INTO SPACE?

Yes! Since 1976, the regulatory body for objects sent into space is the United Nations. Responsibility for the maintenance of a register of objects – and that any planned launches are sufficiently separated – lies with the United Nations Office for Outer Space Affairs. To date, over 86 per cent of all satellites, probes, landers and crewed spacecraft launched into Earth orbit or beyond have been registered with the UN. Those that haven't generally predate 1976.

The latest numbers show that there are about 6,250 satellites in Earth orbit, of which about 3,900 are still operating. But Earth's space environment is populated with a further 28,210 pieces of 'space junk' and up to 129 million smaller fragments that can't be tracked. Such material is monitored optically or with radar by various agencies, often as members of the Inter-Agency Space Debris Coordination Committee.

Even so, satellite operators are finding it harder to avoid the potential for catastrophic collisions. In 2009, satellites Iridium 33 and Kosmos 2251 collided above Siberia, while the latest near-miss happened on 9 April 2021 when a US meteorological satellite passed within an estimated 21m of part of a Soviet rocket launched in 1971.

Furthermore, some experts warn that a 'critical mass' of space junk may be only a few decades away. This is where one major collision results in an uncontrollable chain reaction.

Although it may be possible to gather or destroy space debris, it seems likely that some form of 'space traffic control' may soon be required – and that future satellites will include autonomous collision avoidance systems. ***AGu***

WINNER

Ian wins three books from Quarto Publishing's *30-Second* book series, including *Oceans*, *Space Travel* and *Numbers*, worth £44.97. Each book features 50 exciting concepts, with every one broken down into an easily digestible summary that takes just 30 seconds to understand.
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GETTY IMAGES X2 ILLUSTRATION: DAN BRIGHT

THE EXPLAINER

CAN YOU REALLY CHANGE YOUR PERSONALITY?

WHAT IS PERSONALITY?

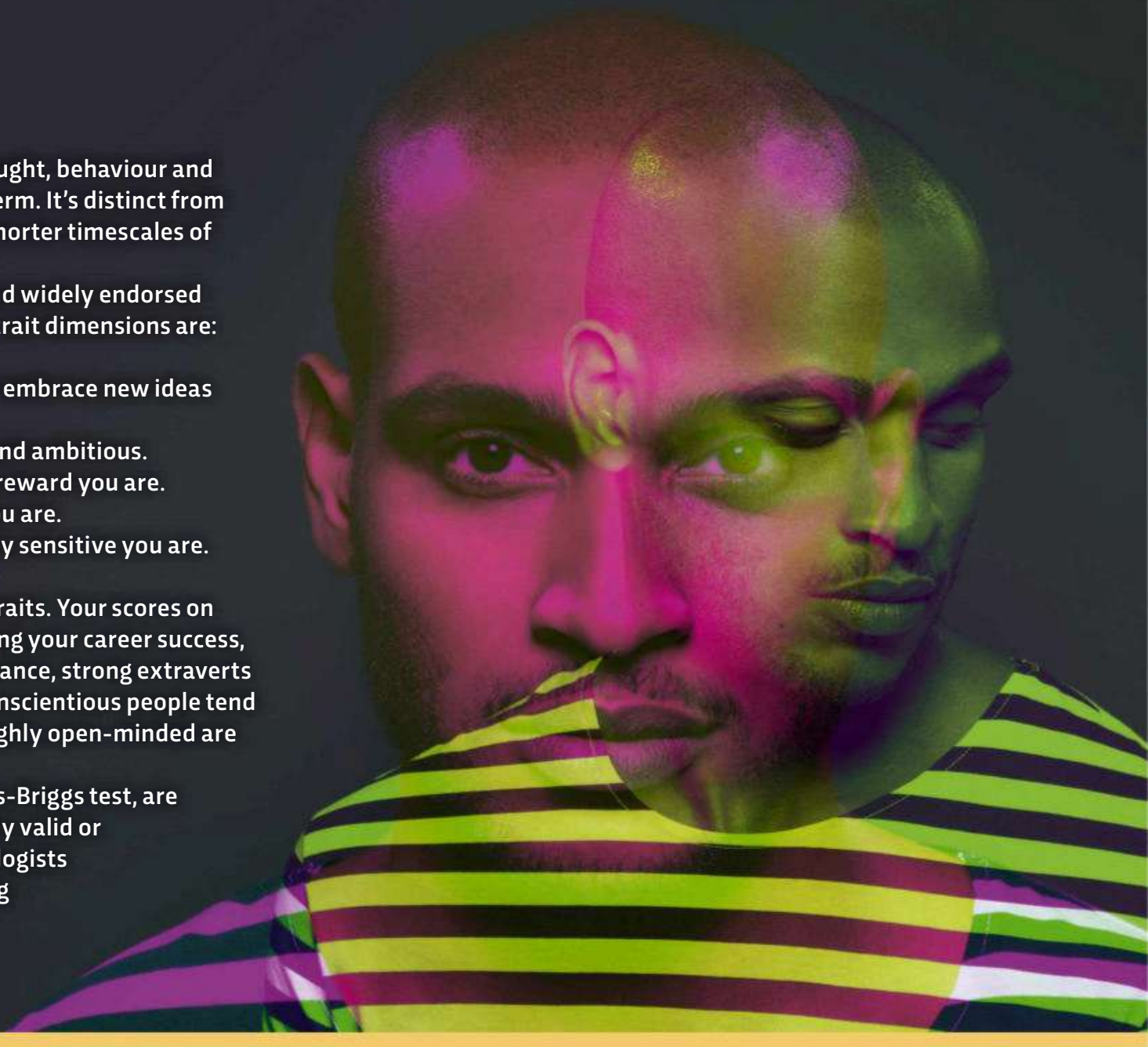
Your personality reflects your habits of thought, behaviour and emotions as they play out over the longer term. It's distinct from moods or emotional states that vary over shorter timescales of minutes or hours.

According to the most evidence-based and widely endorsed OCEAN model of personality, the five main trait dimensions are:

- Open-mindedness: how willing you are to embrace new ideas and experiences.
- Conscientiousness: how self-disciplined and ambitious.
- Extraversion: how sociable and drawn to reward you are.
- Agreeability: how friendly and trusting you are.
- Neuroticism: how anxious and emotionally sensitive you are.

Together these are known as the 'Big Five' traits. Your scores on them are incredibly consequential, predicting your career success, happiness and even your longevity. For instance, strong extraverts tend to live shorter, happier lives. Highly conscientious people tend to do better at work. And people who are highly open-minded are less vulnerable to dementia.

Some personality tests, such as the Myers-Briggs test, are popular, but they're not seen as scientifically valid or reliable by mainstream personality psychologists – such tests don't tap effectively into the Big Five and you're likely to receive different scores each time you take them.



HOW MUCH OF OUR PERSONALITIES ARE GENETIC?

About 30 to 50 per cent of the variation in personality between people stems from differences in the genes they inherited from their parents. Of course, that still leaves plenty of scope for early and later life experiences to leave their mark, such as marriage and divorce, illness, job losses, parenthood, peer pressure and bereavement.

In fact, it used to be believed that personality was set in stone from around the age of 30, but longitudinal studies following the same people over decades have shown that personality traits continue to change over a lifetime.

It's true that personality tends to stabilise the older we get, but that's because many of us tend to settle into grooves of lifestyle and routine. With the right approach and determination, there's no reason that you can't deliberately alter your personality traits.

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HOW CAN I BECOME MORE EXTRAVERTED?

Any attempts at personality change are more likely to succeed if they're in the service of some larger value, cause or goal, rather than for the sake of it – or to please someone else.

For instance, striving to be more extraverted to help your burgeoning business via a greater willingness to network is more likely to succeed than attempting to be more extraverted just because you think it would be desirable.

Another golden rule is that you need to change your ways of thinking and behaving until they become habitual.

A good method for becoming more extraverted is using 'if-then' plans to boost your sociability, such as 'If I'm sat on a train near a stranger, then I'll make an attempt to start a conversation'. Also, it's key to reappraise your anxiety in social situations as excitement.

It will be a challenge at first, but studies suggest that even strong introverts tend to enjoy acting extraverted more than they think they will.

DID LOCKDOWN CHANGE MY PERSONALITY?

It might have. Any radical, lasting change in circumstance, social company and emotional challenge is likely to influence personality traits.

That said, lockdown was not the same for everyone and we all came into it with a different set of baseline traits. Some people ended up living in social isolation for months; others had to juggle childcare and home working; while those in healthcare, essential retail or public transport were still working in the same environment but facing new challenges. This variety of lockdown means there's no such thing as a single 'lockdown personality'. Rather, the effects of lockdown will be individual to you.

For instance, if you've been isolated and become lonely, there's evidence this can prompt reductions in extraversion. But being aware of these influences on your personality could help you deliberately combat them and get yourself back on track.

HOW CAN I BECOME MORE OPEN-MINDED?

The older we get, the more closed-minded we tend to become; that is, more stuck in our ways and beliefs. One way to counter this is to deliberately seek out new experiences and perspectives.

Pandemic restrictions allowing, make a pledge to try a different restaurant each time you eat out, for instance, or visit different destinations for your holidays rather than always returning to the same spot. Consider dabbling in new art forms, such as poetry or opera, that you might not have tried before.

Less obvious is to work on your physical and mental fitness, for example by taking regular walks and completing mind games and puzzles.

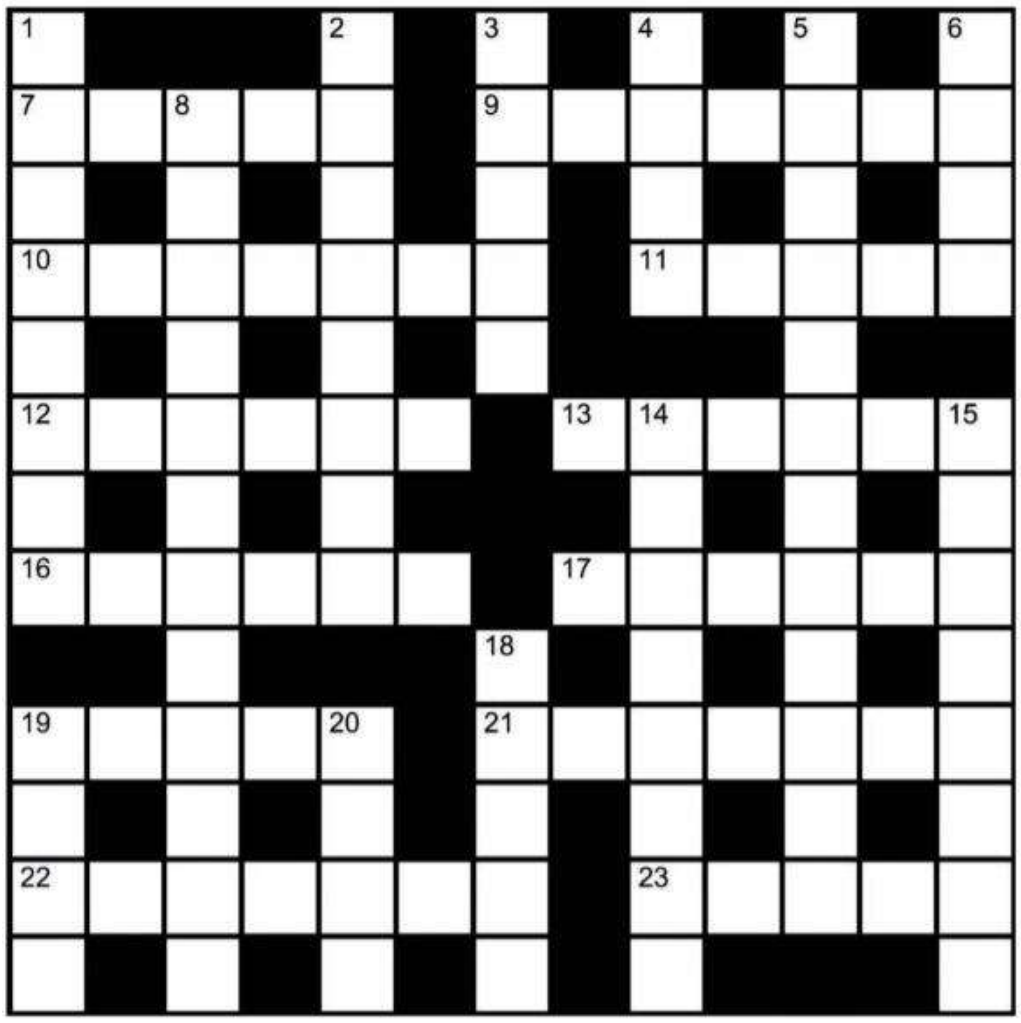
Such activities have been linked with increases in open-mindedness. The theory is that they help build your confidence and therefore your willingness to try new things.

by DR CHRISTIAN JARRETT

Christian is a psychologist and author of Be Who You Want: Unlocking The Science of Personality Change *(£14.99, Robinson).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 Avoid commitment to a boundary (5)
9 Key specialist treated pain first (7)
10 Answer – gold generator (7)
11 Label changed – about to expel air (5)
12 Unusual origin almost includes large source of energy (3,3)
13 Judge sailor, after pressure is established beforehand (6)
16 Clean off tip of the knife (6)
17 Office sends boyfriend around ancient city (6)
19 Entertainment, having taken to bed (5)
21 After dessert, daughter dabbled (7)
22 Considerate communist and family (7)
23 Get volatile liquid delivered there (5)

DOWN

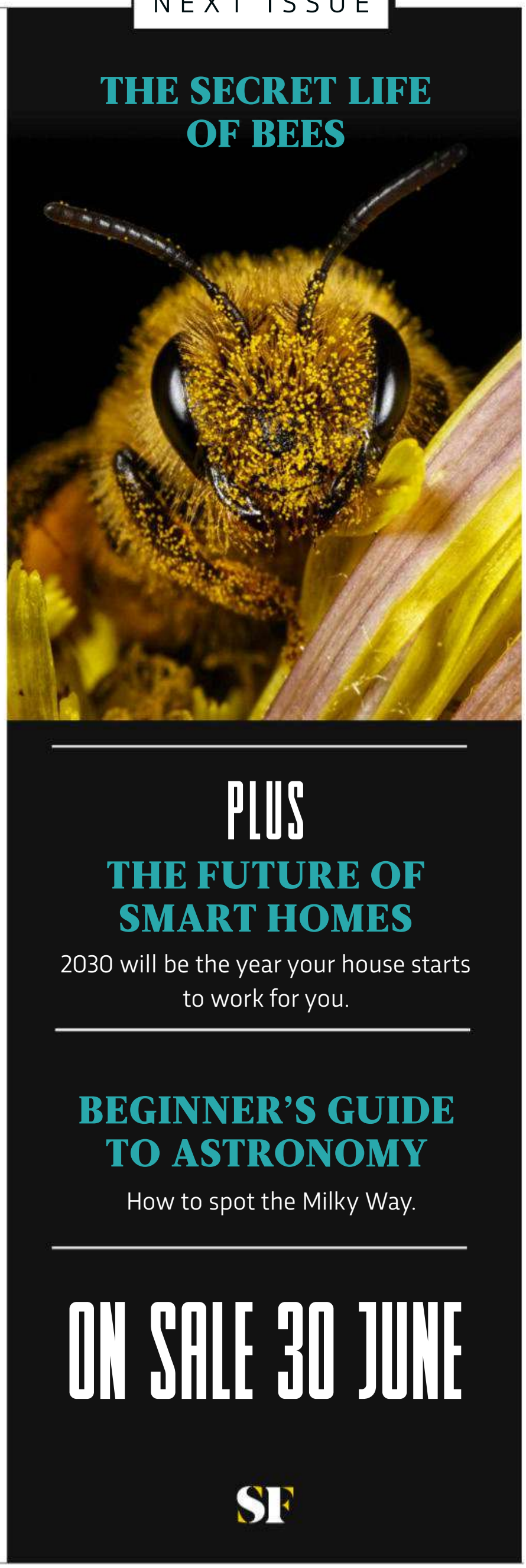
1 Pass round a previously cleaner form of carbon (8)
2 Old race about life-changing data (4,4)
3 Small wine, just for fun (5)
4 Preserve business, initially, in the post (4)
5 Doctor's invoice for certificate (4,2,6)
6 Snag, not initially an irritation (4)
8 Sound before one's numbers are up (8,4)
14 Once more, joined military group in the grass (8)
15 Limit sure to upset Ray (8)
18 Investigate a place of work (5)
19 Unreliable person, left out, is a phoney (4)
20 Loner depressed about bore (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE



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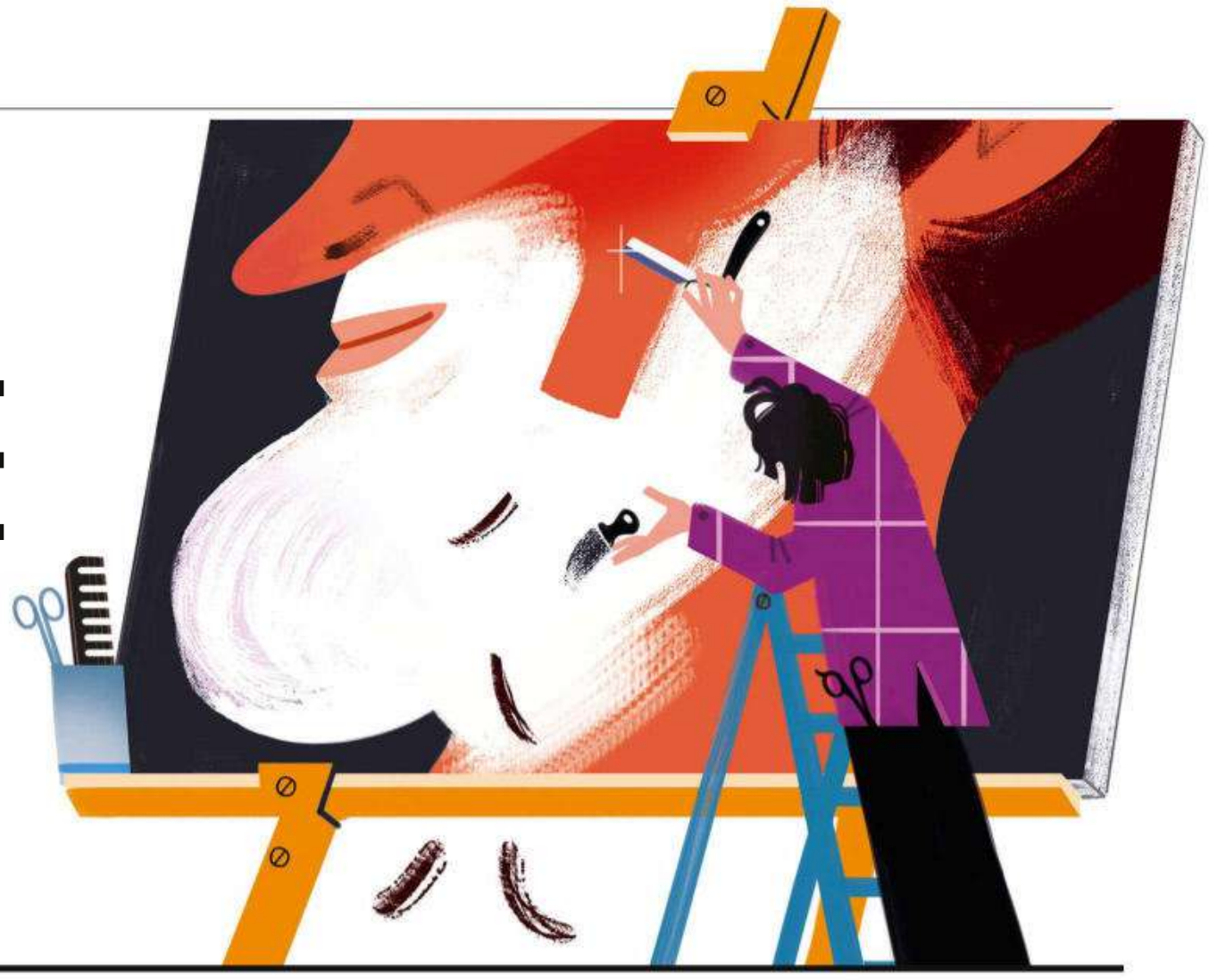
A SCIENTIST'S GUIDE TO LIFE

HOW TO HAVE THE ULTIMATE SHAVE



FED UP OF NICKS, CUTS AND RASHES? THIS MONTH, **DR MARY SOMMERLAD** FROM THE BRITISH ASSOCIATION OF DERMATOLOGISTS EXPLAINS HOW TO HAVE THE ULTIMATE SHAVE...

WET SHAVING IS RECOMMENDED.

Dry shaving with an electric razor is good if you're trying to maintain stubble or have a history of ingrown hairs, but if you're after a clean, smooth shave, then wet shaving is the way to go. To avoid irritation, keep the blade clean and sharp, so if it's disposable, change it regularly.

FIVE BLADES AREN'T NECESSARILY BETTER THAN TWO...

... But a razor with multiple blades might help you reach some of the less accessible areas of your face more easily, such as under your jaw. It's about being able to move the tool around your face without having to keep changing your position.

MOISTURISE AND EXFOLIATE.

Moisturise regularly to avoid dryness. Choose a product that nourishes the skin barrier and suits your skin type, and use a liquid exfoliator every day. Exfoliators remove dead skin cells and help open up hair follicles – particularly helpful if you're prone to ingrown hairs.

PREPARATION IS EVERYTHING.

Wash, exfoliate and moisturise the night before, then, in the morning, gently cleanse your face. Avoid scrubbing as this can cause inflammation. Next, place a clean, warm, damp cloth on your face for a few minutes. This helps open up the follicles and makes for a closer shave. After that, apply a shaving cream or balm, to reduce the drag of the razor against your skin.

TAKE TIME WITH THE MAIN EVENT.

Be methodical. Start on one side and work your way across. Rinse the razor after every stroke. I recommend shaving in the direction of hair growth – downwards for most people.

TAKE CARE WITH THE AFTERSHAVE.

When you've finished shaving, rinse off any remaining product and apply your moisturiser. If you're going to use aftershave, don't slap it on your face like they do in the films; apply it gently, after rubbing some into your hands. Aftershave doesn't prevent you from getting ingrown hairs and the alcohol can really sting.

EXPENSIVE PRODUCTS AREN'T NECESSARILY BETTER THAN CHEAPER ONES.

More expensive products don't always contain more expensive ingredients. You're often paying for the packaging and the marketing. That said, cheaper products are sometimes bulked out with 'filler' ingredients. If you're looking for a liquid exfoliator, make sure that glycolic acid is listed in the first six ingredients. Similarly, if you're after a moisturiser, look for ingredients like shea butter, glycerine and hyaluronic acid near the top of the list.

MALE AND FEMALE SHAVING PRODUCTS ARE THE SAME.

The only difference is the price. Studies have shown the existence of a gender-based price discrimination, or 'pink tax', where certain products aimed at women cost more than those designed for men.

BE KIND TO NICKS AND CUTS.

They happen. Just don't go sticking bits of toilet paper to your face, as they dry and stick. Instead, apply pressure to the area if needed, then dab on a little barrier cream. Creams that contain vitamin B5 or 'panthenol' are good. Then moisturise on top. Cuts heal well in a moist environment, so a moisturiser aids the process.

SHAVEN HAIR DOES NOT GROW BACK THICKER

It's a myth. The hair remains exactly the same thickness. All that happens is that the tips of the hair can look blunter, giving the illusion of thicker hair. SF

DR MARY SOMMERLAD
Mary is a consultant dermatologist.
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Your nan was wrong: your hair won't grow back thicker, coarser or darker if you shave it.

2

Keep shaved skin happy by moisturising often and applying a liquid exfoliator to remove dead skin cells.

3

Although this advice is given in regard to faces, it's just as applicable to armpits, legs, chests and... elsewhere.

ILLUSTRATION: LUCA ZARANTONELLO

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